



**CALIFORNIA
ENERGY
COMMISSION**

**Conceptual Design Energy Analysis
Tool (CDEAT) Research &
Development – Final Report**

CONSULTANT REPORT

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

What follows is the final report for the Conceptual Design Energy Analysis Tool Project, #500-98-023 conducted by GeoPraxis, Inc. The report is entitled Conceptual Design Energy Analysis Tool (CDEAT) Research & Development – Final Report. This project contributes to the PIER Buildings End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: <http://www.energy.ca.gov/research/index.html> or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

Building designers have long dreamed of being able to easily estimate the energy performance of a building without having to become expert users of complex engineering software. The goal for the Conceptual Design Energy Analysis Tool (CDEAT) project was to develop a commercially viable software tool that would enable architects and developers to estimate a building's energy usage and cost during the early stages of architectural design.

Objectives

The key objectives of the project were to:

- Design and develop the Energy Analysis Module (EAM) software
- Demonstrate that the EAM is useful, credible, and affordable to 3D-CAD users, and can be commercialized.

The CDEAT project was structured in three phases designed to develop and bring the new technology to the brink of commercialization:

- Phase 1: Market and Technical Benchmarking Research
- Phase 2: Energy Analysis Module (EAM) Software Development
- Phase 3: Market Preparation and Outreach

Outcomes

The major accomplishments of the project were:

- Eight distinct technical and market research activities designed to probe the design practices of building designers, including interviews, a technical colloquium, a web survey and a focus group
- A “Working Technical Specification” resulting from an intense period of creative – almost cross-cultural – collaboration between the building energy engineering simulation experts (from GeoPraxis) and the architectural 3D CAD experts (from Artifice).
- The Energy Analysis Module (EAM) – an easy-to-use web-based energy software tool that provides a quick estimate of energy use and cost and automatically creates a robust simulation model to share with other design team members
- A Software Developers Kit (SDK) – extensive documentation and tools to help upstream CAD firms integrate the EAM software into their applications
- Demonstrated EAM interoperability with DesignWorkshop (CAD) and DOE-2 (energy analysis).

In addition to the PIER-funded activities originally planned, several major beyond scope efforts were accomplished either at GeoPraxis' own initiative or as matching contributions. These included:

- Green Building XML (gbXML) – an open data format for sharing architectural CAD data with energy analysis, facilities management, and other downstream tools (PIER-funded)
- Supplemental market research on design practices (ARTI-funded)

- Preparation of a GUI interface development plan for DOE's next generation simulation engine, EnergyPlus (NREL-funded)
- DesignWorkshop enhancements and middleware (Artifice-funded)
- Trane TRACE gbXML import feature development (Trane-funded)
- Pre-launch software demonstrations and gbXML standards promotion (GeoPraxis-funded)
- Demonstrated downstream EAM interoperability with several well-known energy analysis tools: TRANE Trace 700, eQuest/DOE-2, PowerDOE, and EnergyPlus_{beta} (GeoPraxis-funded).

Green Building XML (gbXML), a beyond scope deliverable of the project, is a highly innovative and expeditious solution to the problem of how to share data between 3D-CAD and energy simulation software. In May of 2000, GeoPraxis decided to publish and share the gbXML schema openly with other software developers worldwide to expedite the significant economic and environmental benefits to come from linking the two types of software. Based on Extensible Markup Language (XML), gbXML is also the draft schema for the International Alliance for Interoperability's aecXML Building Analysis & Performance working group. Efforts are underway to coordinate gbXML and other aecXML standards with IAI's ongoing Industry Foundation Classes standards development effort. The schema is published and maintained at www.gbXML.org. Because gbXML is significantly more accessible and easy to implement than other building data format alternatives, and especially because it open to the public, gbXML may ultimately become the most beneficial long-term result of the entire CDEAT project.

The initial budget underestimated the amount of effort required to complete the final tasks of the project as originally planned. Because of these constraints, the software development has reached the "alpha" stage, indicating that basic functionality can be demonstrated. While "beta" testing (with prospective end users) was originally anticipated to occur under this project, the software will be beta tested only after additional funds become available.

After beta testing is complete, the EAM technology will be made available directly to end users on the new GreenBuildingStudio.Com website. End users of gbXML-compliant CAD software will have the option of subscribing to GreenBuildingStudio.Com, where they will be able to use the EAM software and model processing service as a hosted ASP application. GeoPraxis will also license Green Building Studio technology for branding and integration by other software or service providers. GeoPraxis is actively seeking funding to complete the beta testing and launch the Green Building Studio from the California utility participants in the Emerging Technologies Coordinating Council (ETCC) and other sources.

Conclusions

The CAD-interoperable EAM software makes significant productivity improvements possible by greatly reducing the amount of time required to do plan take-offs and build up the simulation model. GeoPraxis' own energy engineers report that even though it is still at the alpha stage, the EAM tool already cuts the time required to build an eQuest/DOE-2 simulation model in half. Results from the "Willingness to Pay" questions included in the web survey of design professionals suggest that the service will be considered an excellent value at the retail price point planned.

Key members of the product and business development teams of all the leading CAD OEM vendors have indicated great interest in the results of the CDEAT project. Market leaders AutoDesk and Bentley have each registered to review the SDK. Representatives of both firms and Trane have prepared letters (Appendix III) in support of the remaining R&D needed to bring the EAM to market.

The technology realized through this ambitious project represents a major breakthrough in building energy analysis software. As a direct result of this groundbreaking research and development, Californian's will soon realize significant beneficial impacts on building end use energy efficiency — impacts that will continue for many years to come.

Benefits to California

While the significant forecasted energy and demand savings will not begin to accrue until the EAM is widely commercialized, the EAM technology is already being used in its alpha stage by GeoPraxis engineers to reduce the amount of time spent conducting take-offs for new building design assistance projects. Rather than enter plan information into eQUEST/DOE-2 directly, the engineer builds a DesignWorkshop 3D-model, imports the model into the (soon to be integrated) EAP creating the mono-planarized gbXML file, and then submits the gbXML file to the online EAM. The resulting DOE2.2 file can then be read into eQUEST for detailed comparative energy engineering analysis. Though many steps are still involved at this stage of development, GeoPraxis engineers already report time savings of 50 percent over conventional take-off data entry. Based on these early results, the technology developed under the CDEAT project appears very likely to generate substantial economic and environmental benefits to California ratepayers in the years to come.

Recommendations

Recommended actions for the Commission to take in the future include:

- Monitor and support other research and development activities (funded by PIER or others) that leverage (and do not undermine) the CDEAT project's commercialization achievements
- During the Commission's review of JJ Hirsch Associates' application to certify eQUEST for use as a Title-24 compliance tool, consider eQUEST's ability to read the files produced by the EAM to be an added benefit to end users
- Consider providing PIER funding for Beta testing of the EAM involving practicing design professionals that are prospective end users of this technology
- Add gbXML-based interoperability to tools that are 1) already popular with California-based building designers or, 2) would be highly beneficial to California electricity ratepayers if more widely used in the design of California buildings
- Publish in gbXML the technical performance specifications of key high performance building products that are targeted for rebates and other commercialization assistance by California's energy efficiency programs.
- Develop automated design decision assistance tools that save California architects time in researching and comparing the costs and benefits of high performance building products and design alternatives.

Abstract

The goal for the Conceptual Design Energy Analysis Tool (CDEAT) project was to develop a commercially viable software tool that would enable architects and developers to estimate a building's energy usage and cost during the early stages of architectural design. The key objectives of the project were to:

- Design and develop the Energy Analysis Module (EAM) software
- Demonstrate that the EAM is useful, credible, and affordable to 3D-CAD users, and can be commercialized.

The major accomplishments of the project were:

- Eight technical and market research activities designed to probe the design practices of building designers, including interviews, a technical colloquium, a web survey and a focus group
- Green Building XML (gbXML) – an open data format for sharing architectural CAD data with energy analysis, facilities management, and other downstream applications
- The Energy Analysis Module (EAM) – an easy-to-use web-based energy software tool that provides a quick estimate of energy use and cost and automatically creates a robust simulation model to share with other design team members
- Software Developers Kit (SDK) – extensive documentation and tools to help upstream CAD firms integrate the EAM software into their applications
- Demonstrated EAM interoperability with DesignWorkshop (3D CAD) and several well-known energy analysis tools: TRANE Trace 700, eQuest/DOE-2, PowerDOE, and EnergyPlus_{beta}.

After beta testing, the EAM technology will be made available directly to end users via ASP at www.GreenBuildingStudio.Com. The CAD-interoperable EAM software makes significant productivity improvements possible and represents a major breakthrough in building energy analysis software.

1.0 Introduction

1.1 Background and Overview

Building designers have long wanted the ability to easily and inexpensively estimate the energy performance of a building while it is still in the schematic phase of design. With energy prices a growing concern, building owners and developers need better estimates of what it will cost to operate their new buildings. The goal for the Conceptual Design Energy Analysis Tool (CDEAT) project was to develop a commercially viable software product that would facilitate the estimation of building energy consumption during the early stages of architectural design. The work was designed to produce an affordable, useable software tool having superior performance and other qualities that previously did not exist in any other commercially available product.

The project was designed to support the PIER program objective of improving the energy cost/value of California's electricity. This goal was to be accomplished by providing architects, design/build contractors and developers with reliable estimates of a proposed, new building's energy performance while it is still in its earliest stage of design. By acting on this information, design professionals can modify their preliminary designs to reduce energy use and costs throughout a building's entire lifecycle.

1.2 Project Objectives

The stated objectives at the outset of the project were to:

1. Design and develop the Energy Analysis Module (EAM) software
2. Demonstrate that the EAM is useful and credible to target users
3. Demonstrate that the EAM is affordable to target users
4. Demonstrate that the EAM can be successfully commercialized

During the course of the project market research findings, new technology developments in the marketplace, and budget constraints, all produced changes to the original project plan. Nevertheless, each of the project's original objectives was accomplished. While financial constraints reduced the measurement of accomplishments from what was originally planned, the project outcomes demonstrate that the technical and commercial viability of the technology is well established.

A more comprehensive discussion of objectives and accomplishments is contained in the Project Outcomes section below.

1.3 Report Organization

The remainder of this report describes the Project Approach, the Project Outcomes, and the Conclusions and Recommendations resulting from the project. A Glossary and References provide further detail for the reader interested in going deeper. The Appendices contain the major deliverables of the project, including the Market Research Reports, the Work Plan, the Specification, the gbXML documentation, and the Production Readiness Plan.

2.0 Project Approach

The CDEAT project was structured in three phases designed to develop and bring the new technology to the brink of commercialization:

- Phase 1: Market and Technical Benchmarking Research
- Phase 2: Energy Analysis Module (EAM) Software Development
- Phase 3: Market Preparation and Outreach

The project began with the Phase 1 Initiation Plan. Phase 1 collected unprecedented market research on the design practices and preferences of building design professionals that use 3D CAD software. During this phase, the team also explored the technical challenges of previous attempts to bring energy analysis software to this influential population. This research greatly helped to explain why several previous attempts to bridge the gap between architectural CAD and building energy simulation software had failed, and what problems to avoid. The lessons of Phase 1 were summarized in the Project Work Plan, which became the foundation for the remaining tasks of the project.

Phase 2 began with an intense period of creative collaboration between the building energy engineering simulation experts (from GeoPraxis) and the architectural 3D CAD experts (from Artifice). Rarely do architects and engineers take the time to so carefully consider the respective technical skills and perspectives of the other. Nevertheless, this almost “cross-cultural” dialogue was considered absolutely necessary to realize bi-lateral data sharing or “interoperability” between these two domains. From the outset it was clear to all that the success of the project depended on each party being able to clearly communicate their own technical requirements, and to fully understand the needs of their counterparts. The result of this collaborative effort was the development of three key technical documents:

1. A detailed technical specification for the Energy Analysis Module (EAM), outlining the software development tasks ahead for GeoPraxis
2. the Green Building XML schema (gbXML), a self-describing data format or language for sharing building-related data between CAD and energy simulation software, and
3. the Software Developers Kit (SDK), a guide for Artifice (and ultimately other CAD developers) to help them prepare and export their data in gbXML format for downstream use by the EAM.

The remainder of Phase 2 was consumed with building out and testing the software code envisioned by these specification documents.

Phase 3 overlapped with the culmination of Phase 2, and included the pre-commercialization research and production readiness planning needed to prepare the software for market. As of this writing, gbXML has already been successfully implemented by several third party software developers; several more are considering implementation. Clearly, the commercialization of this PIER-funded technology is already well underway.

2.1 Modifications to the Approach

The original scope of the end user telephone survey planned in Phase 1 was modified because several excellent secondary sources were discovered after speaking with key informants and

reviewing the literature. Based on the findings of this early research, the team decided that a web-based survey and the addition of a focus group offered a better means of meeting the research objectives.

The initial budget underestimated the amount of effort required to complete the final tasks of the project as originally planned. Because of these constraints, the software development has reached the “alpha” stage, indicating that basic functionality can be demonstrated. While “beta” testing (with prospective end users) was originally anticipated to occur under this project, the software will be beta tested only after additional funds become available. Even so, the technology realized through this ambitious project represents a major breakthrough in building energy analysis software. As a direct result of this groundbreaking research and development, Californian’s will soon realize significant beneficial impacts on building end use energy efficiency — impacts that will continue for many years to come.

3.0 Project Outcomes

The major outcomes of the CDEAT project are itemized below, organized according to each of the project objectives to which they pertain. All outcomes listed are PIER-funded, unless otherwise noted.

3.1 Objective 1: Design and Develop the Energy Analysis Module (EAM) Software

As the major objective of the project, EAM design and development related outcomes are organized below under the five following subcategories:

- Technical Benchmarking and Market Research
- Technical Benchmarking and Market Research (Matching/Third-Party Funded)
- Software Specification Documents
- Software Technology
- Software Technology (Matching/Third-Party Funded)

The major outcomes of each are described below.

3.1.1 Technical Benchmarking and Market Research

In preparing the design of the EAM, eight distinct technical and market research activities were undertaken by GeoPraxis with PIER funding:

Key Informant Interviews: Completed July 1999. Forty-one experts in nine different expertise categories (e.g., Design Practitioner, CAD Vendor, Energy Analysis Software Developer, etc.) were interviewed, allowing the team to identify and explore technical and market issues, as well to identify relevant secondary source references. A complete discussion was provided in Deliverable 2.1.1 (Key Informant Interview Summary/Secondary Source Review).

Secondary Source Review: Completed August 1999. Based on the recommendations of key informants and augmented by extensive web research, a number of excellent secondary information sources were identified and obtained. These materials formed the foundation of our market research in support of the EAM project. Analysis of this secondary research allowed the team to avoid redundancy, improve the quality, and target the scope of subsequent primary data collection activities. A complete discussion was provided in Deliverable 2.1.2 (Annotated Bibliography).

Technical Colloquium: Completed July 1999. A technical workshop was held on July 8, 1999 at the PG&E Pacific Energy Center in San Francisco. The colloquium provided a technical forum bringing together seven experts from the energy simulation and 3D-CAD software development communities. The colloquium allowed the development team to explore the lessons learned from previous attempts to integrate CAD and energy analysis software and then to brainstorm ideas, identify problems, and propose solutions. A complete discussion was provided in Deliverable 2.1.3 (Technical Colloquium List of Invitees and Summary Report).

3D-CAD User Focus Group: Completed August 1999. Nine 3D-CAD using attendees participated in a formal focus group held in San Francisco on August 10, 1999. This provided us with a forum to elicit feedback from architects on the usefulness and preferred methods of

integrating green building and energy analysis capabilities into 3D CAD design tools. A complete discussion was provided in a beyond scope deliverable, the Focus Group Results and Analysis Report (Appendix I).

3D-CAD User Web Survey: Completed March 2000. A detailed online survey of design professionals (limited to personal users of 3D CAD software) was launched on October 8, 1999 and completed on December 7, 1999. The survey, hosted by Artifice in association with DesignCommunity.Com, attracted 774 interested respondents and 419 eligible participants from 32 countries. The survey instrument and sample design were provided in Deliverable 2.1.4 and a complete discussion of the survey results was provided in Deliverable 2.2 (Appendix II).

Project Work Plan: Completed November 1999. The major findings of Phase 1 were summarized in the Project Work Plan (Deliverable 2.3.1), which became the foundation for the remaining tasks of the project.

AEC Systems 2000: Completed June 2000. GeoPraxis undertook a pre-product launch trip to the A/E/C Systems 2000 trade show in Washington DC (June 6-8, 2000). Discussions were held with CEO's and other executive representatives of nearly all the architectural CAD vendors (and emerging CAD Application Service Providers) present at the show. Without exception, all stated they were "very interested" in pursuing how an XML-linked energy analysis module could be integrated into their business and product development plans. The commercialization plan benefited greatly from this very timely future "customer" and "strategic partner" input.

LBNL and CIFE Seminars: Completed December 2000. On June 16, 2000, over 40 individuals from academia, government, and industry gathered at Lawrence Berkeley National Laboratory (LBNL) to review issues involving the integration of aecXML and the IAI/IFC's. GeoPraxis was invited to deliver a presentation on gbXML. In September of 2000, GeoPraxis attended a workshop at Stanford University's Center for Integrated Facility Engineering, meeting with many A/E/C information technology industry leaders and researchers. On December 18, 2000, representatives from LBNL, GeoPraxis and the CEC met to discuss potential opportunities for collaboration between the BLIS-XML and gbXML efforts. The result of this meeting was that GeoPraxis agreed to provide the gbXML tags and LBNL agreed to use the same nomenclature when developing new extensions to the IFC.

3.1.2 Technical Benchmarking and Market Research (Matching/Third-Party Funded)

In addition to the PIER-funded technical and market research activities called for under the original project work plan, GeoPraxis was able to generate sufficient interest in other R&D organizations to secure supplemental funding for research that was of direct relevance to the CDEAT project:

"State-of-the-Art Whole Building Simulation Software Review" (Funded by ARTI): Completion anticipated Q2, 2002. Beginning in 2000, GeoPraxis, in conjunction with Architectural Energy Corporation (AEC) and CDH Energy, undertook a major study of building energy simulation software industry's research and development activities. The work was funded by the Air-Conditioning and Refrigeration Technology Institute (ARTI). The goals of the project were to define building simulation and design tool user requirements, survey the capabilities of existing tools, assess the fit between existing tools and user requirements, and provide guidelines for further tool development. It is expected that ARTI will release the final report in the second

quarter of 2002. Under this project, GeoPraxis led two major primary data collection and analysis activities:

- **ARTI Web Survey of Design Professionals:** The web-based survey allowed the team an ideal opportunity to ask new questions of the same population previously surveyed under the PIER-funded survey one year earlier. This survey allowed the team to investigate the requirements for innovative building energy simulation tools that facilitate the practice of integrated whole-building design, improvements in energy efficiency, comfort, and indoor environmental quality with minimal impacts on construction costs. The survey attracted 337 interested respondents and 198 eligible participants from 17 countries. The survey was launched on October 18, 2000 and completed on December 15, 2000.
- **ARTI Focus Groups of Design Professionals:** GeoPraxis organized and led two focus groups, one in Denver, CO (November 14, 2000) and one in Syracuse, NY (December 12, 2000). These discussions allowed us to gather opinions from design professionals (primarily Architects, Engineers, and Design/Build Contractors) on the types of software innovations they'd like to see that would help them design buildings that are more comfortable to live in, more productive to work in, and more energy and resource efficient. This research probed the decision-making processes and the prevailing tool use practices and preferences of building designers. The research was organized by the specific energy-related design decisions that must be made on every project.

EnergyPlus® Target User Task Analysis (Funded by NREL): Completed March 2002. GeoPraxis prepared an Interface Development Plan for outlining the development of a user-friendly, graphical user interface (GUI) for EnergyPlus, the Department of Energy's building energy simulation program. The National Renewable Energy Lab provided funding for the plan. The proposed GeoPraxis GUI would take the form of an IDEA Server® application, and would integrate gbXML. Prior to developing the plan, GeoPraxis conducted additional primary market research among target A/E/C users of CAD software. The goal of the research was to better understand the process typical design firms use at the critical decision points that affect a building's energy use. GeoPraxis conducted four daylong "task analyses" in November and December 2001. Three types of firms involved early in a building life cycle (architecture, engineering, and energy services firms) participated in this research.

GeoPraxis also collected pre-launch market intelligence and publicity by attending several key industry forums and demonstrating the technology under development:

AEC Systems 2001 (Funded by GeoPraxis): Completed June 2001. The development team held a pre-release demonstration reception for news media at the AEC Systems trade show in Chicago on June 18, 2001. This event was by-invitation only and was attended by several key members of the CAD trade press and selected OEM CAD and HVAC analysis tool vendors. Valuable feedback resulted from this meeting, including a wide-ranging discussion of strategic business issues that served to improve the market focus of the Production Readiness Plan.

Pre-launch Demonstration Events (Funded by GeoPraxis): Completed June 2000. Shortly after publication of the gbXML schema, GeoPraxis attended two professional meetings to discuss the schema and demonstrate it in action using the alpha stage Energy Analysis Module (EAM). In June 2000, GeoPraxis demonstrated how the EAM uses gbXML to interoperate with DOE-2.2

and EnergyPlus (beta). The demonstrations were held at the IAI's aecXML/IFC meeting in Atlanta and at the IBPSA semiannual meeting in Minneapolis. Both of these events indicated growing industry acceptance of the gbXML schema.

AEC Systems 2002 (Funded by GeoPraxis): Completed June 2002. GeoPraxis again attended this key industry conference and trade exposition to update CAD OEM and media representatives on the significant technical accomplishments of the project. GeoPraxis produced a simple brochure summarizing the CDEAT project that was widely circulated at the event. A prominent CAD industry analyst invited GeoPraxis onto a panel to discuss XML developments in the A/E/C industry and to present the team's experience administering gbXML under the Building Performance and Analysis Working Group (aecXML domain of the International Alliance for Interoperability).

3.1.3 Software Specification Documents

Based on the significant market and technical research collected in support of the Energy Analysis Module (EAM) development effort, GeoPraxis prepared three major software specification documents. Only two were called for under the original project work plan. The three specification documents were:

- Energy Analysis Module (EAM) Working Specification
- EAM Software Developers Kit (SDK), and
- The Green Building XML (gbXML) Schema and Documentation

Together, these documents were used to communicate the EAM software's design intent and functional specifications to both internal development team members as well as external developers of potentially interoperable third-party applications. From the outset of the project, this latter group was considered a critical audience. These external stakeholders, while not directly involved with the preparation of project deliverables, were considered key to the software's commercial future.

Each of these documents is described below.

Working Specification: Completed March 2000. The joint GeoPraxis/Artifice development team prepared the working technical specification to guide and coordinate its internal software development activities. This 72-page document began with a summary assessment of the "market problem" and outlined the "solution" the EAM was designed to become. It stipulated that Microsoft Windows 32-bit operating systems were to be the only supported platform for the initial release of the EAM. The program specification included program flow diagrams, and a description of each of the program's constituent modules (standalone 32-bit ActiveX DLLs). The data specification contained descriptions of the CAD data object types to be supported by the EAM, the tables to be included the EAM's library database, and the results the EAM would be capable of displaying. In addition, the specification included the commands and keywords for working with the first simulation engines to be integrated with the EAM (DOE-2.2 and EnergyPlus). Finally, naming conventions were also stipulated. Figure 1 shows an overview diagram from the working specification. The EAM Working Specification was provided as Deliverable 2.4.1 (Version 0.2 completed 3/19/00).

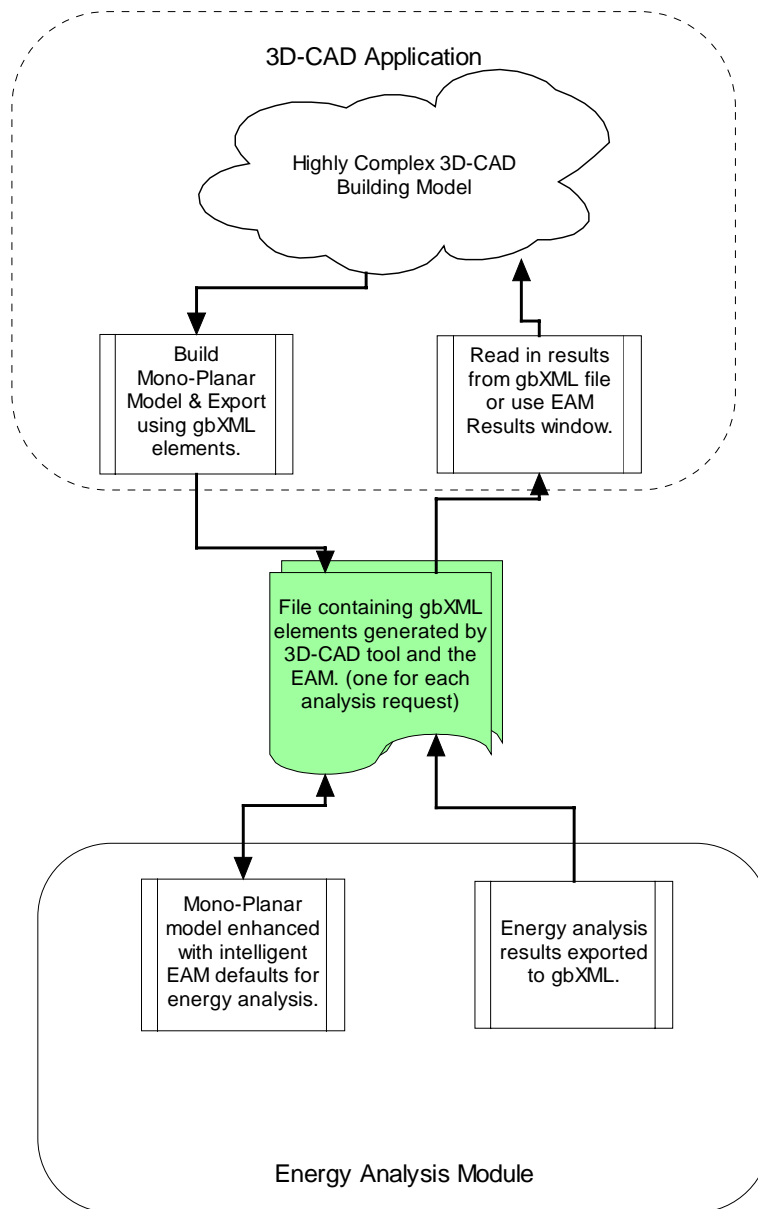


Figure 1. CAD - EAM Data Flow Using gbXML

Software Developers Kit: Completed February 2001. The Software Developers Kit (SDK) was designed to function as a “how-to” manual to assist 3D-CAD OEM developers in enhancing their applications to become interoperable with the EAM using gbXML. The SDK provided a bridge for such programmers between the CAD software conventions with which they were familiar and the minimum requirements of sophisticated building energy simulation analysis engines with which they were not. It was intentionally aimed at technically proficient software programmers with little to no prior knowledge of the principals of thermodynamics or the applied practice of building energy simulation. Given their lack of prior experience with the

requirements of energy simulation modeling, Artifice's input turned out to be invaluable in the development and iterative refinement of the SDK.

The SDK included:

- General development requirements needed to support the EAM,
- Minimum gbXML elements that must be supported,
- Additional elements that may be supported to extend EAM functionality,
- EAM Application Programming Interface (API),
- EAM object rules
- EAM components, and
- Glossary of key EAM concepts.

The project version of the SDK was provided in Deliverable 2.7.2. CAD OEMs may register and download the SDK via the GeoPraxis website (www.geopraxis.com).

The green building XML (gbXML) Schema and Documentation: Completed September 2001. From the perspective of the CDEAT project's original work plan, the XML (gbXML) schema and its corresponding documentation are beyond scope deliverables — and very significant ones at that. Originally, many of the functions that gbXML performs were to have been accomplished deep within the confines of the compiled and proprietary EAM software. In essence, gbXML constitutes the explicitly documented, internal data syntax on which the EAM depends (in particular the “input code”, “DOE-2 code”, “output code”, and database). The gbXML documentation is an online electronic document containing lists, detailed descriptions, and definitions of all the data elements currently supported in gbXML. It diagrams the relationships between each gbXML element, and lists all associated attributes of each element. The gbXML documentation contains sample source code for using each element in practice. It is published and maintained at www.gbXML.org.

In May of 2000, GeoPraxis decided to publish and share the gbXML schema openly with other software developers worldwide to expedite the significant economic and environmental benefits to come from the linkage of CAD software with building energy simulation software. GeoPraxis and the Commission also expect to benefit from this decision because other software developers are more likely to adopt an open data standard than a proprietary one, thus multiplying the usefulness of the EAM software developed under this project. Developers of advanced 3D-CAD tools will usually require much less time to integrate gbXML into their applications than other more complex data formats such as the IFC. The same is true for downstream applications that can use CAD data. Because gbXML is significantly more accessible and easy to implement than other data format alternatives, and especially because it open to the public, gbXML may ultimately become the most beneficial long-term result of the entire CDEAT project.

3.1.4 Developed Software Technology

Originally, the Energy Analysis Module (EAM) development effort was intended to produce a software module for distribution as a “plug-in” component to the proprietary 3D-CAD program, DesignWorkshop®. Instead, in response to the trend toward Internet-based

computing and XML-enabled client/server architecture, GeoPraxis developed a server-based application that can be called from any gbXML-compatible application running on a client computer connected to the Internet anywhere in the world.

The EAM, the primary software technology resulting from the project is described below:

The Energy Analysis Module (EAM) is a software program that enables any 3D-CAD application that supports the Green Building XML schema (gbXML) to access one of the most sophisticated building energy simulation analysis tools in the world, DOE-2.2. The structure of the EAM is such that once enabled, alternative simulation engines can also be called, based on the user's licensing and preference. One of the basic requirements of any 3D-CAD tool supporting the EAM is that it can read and write gbXML files. Figure 2 shows a simple diagram outlining the EAM functionality.

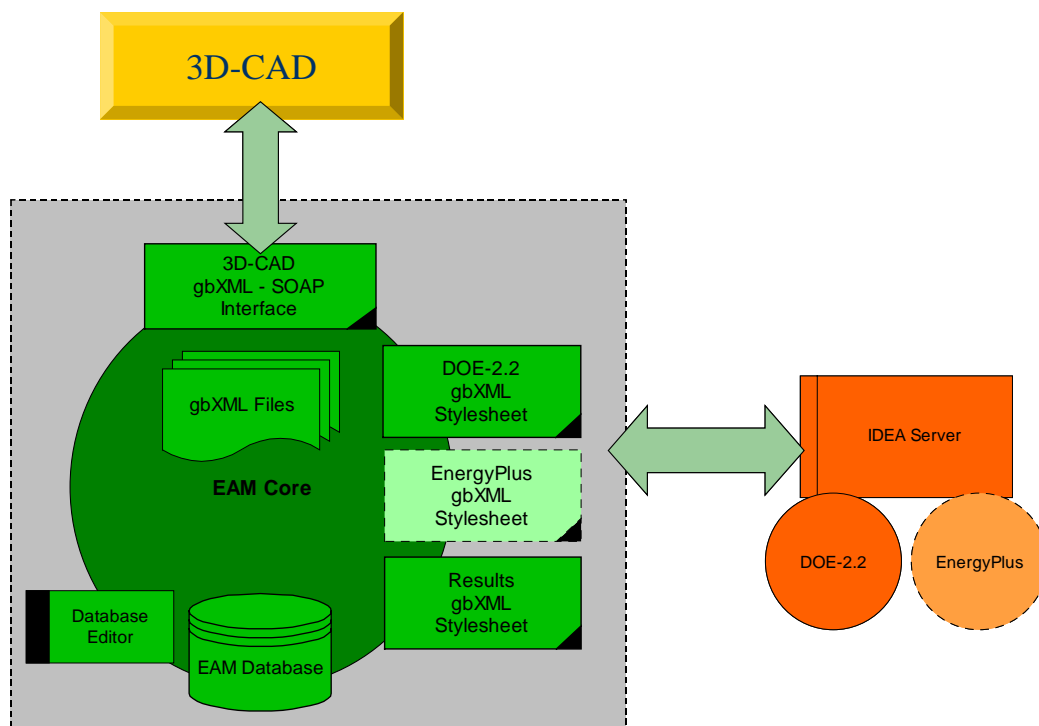


Figure 2. EAM Components and Functionality

The EAM runs on GeoPraxis' web servers and is accessible using the Simple Object Access Protocol (SOAP) over the Internet. The EAM consists of a Visual Basic ActiveX Dynamic Link Library (DLL), a SQL Server database, numerous XSLT stylesheets, and active server page files. To ensure the EAM is available for all platforms it is available over the Internet using the now widely used SOAP protocol. The EAM communicates with GeoPraxis' IDEA Server program, functioning as a pre/post processor for DOE-2, EnergyPlus, and other simulation engines.

The architecture of the EAM was designed to allow CAD developers the most flexibility and the fewest support issues with regard to the technology. Once an Internet connection is established, the EAM only requires the architectural end user to input the location of the building (US zip

code), the type of building, and the geometry of its major components. All other data required to complete a preliminary energy simulation are provided from the EAM database. The EAM uses the user-provided information to expand this simplified dataset to that needed for energy simulation using defaults based on the building practices and codes in a specific region of the world. Currently the EAM is limited to use in US states, with enhanced capabilities in California (due to the availability of high quality data maintained by the Energy Commission). The major sources of the data behind the tool are:

- Commercial Building Energy Consumption Survey (CBECS)
- California Title 24 (June 1, 2001 revision)
- ASHRAE Standard 90.1
- Manufacturers' Technical Specification Sheets
- International Energy Conservation Code (IECC)
- Additional Non-Residential New Construction survey data (sources: state agencies, utilities, etc.)
- Hourly "TMY2" climate data for California's 16 climate zones and several hundred other U.S. locations¹, and
- U.S. Postal Service zip code data set.

The EAM technology will be made available directly to end users on the new GreenBuildingStudio.Com website. End users of gbXML-compliant CAD software will have the option of subscribing to GreenBuildingStudio.Com, where they will be able to use the EAM software and model processing service as a hosted ASP application. GeoPraxis will also license Green Building Studio technology for branding and integration by other software or service providers. Green Building Studio will begin beta testing in the Fall of 2002, subject to the availability of funding.

3.1.5 Developed Software Technology (Matching/Third-Party Funded)

DesignWorkshop Enhancements (Artifice-Funded). Outside the scope of the PIER-funded project, Artifice completed fundamental enhancements to the internal data structure of its preexisting conceptual design 3D-CAD software, DesignWorkshop. These enhancements were required to enable DesignWorkshop to define and export certain properties associated with the geometric objects contained in the CAD file in the format ultimately required by the EAM.

Energy Analysis Preprocessor (Artifice-Funded). The EAP is a middleware software program developed by Artifice independently outside the scope of the PIER-funded project. Artifice designed the EAP to meet dual objectives:

- To meet DesignWorkshop's immediate need to transform and "mono-planarize" the complex (and sometimes trivially imperfect) files produced by CAD software into the simple (but exacting) format required by the EAM and its underlying thermal simulation engine, and,
- To incrementally expand the capabilities of the EAP beyond the minimum needed to support DesignWorkshop, such that the EAP might also be capable of addressing the needs of other CAD developers who might someday attempt to make their applications gbXML-compatible.

TRANE TRACE gbXML Import Feature. The TRANE Company, makers of TRACE 700, a software program popular with mechanical engineers for HVAC system design and sizing have used gbXML to make their program capable of reading in files:

- Exported by the EAM in gbXML, and,
- Exported directly from a 3D-CAD tool capable of producing a gbXML file.

This development effort, reportedly to have taken only 3 weeks of programming labor, was entirely self-funded by TRANE.

3.2 Objective 2: Demonstrate that the EAM is Useful and Credible to Target Users

The steps for using the EAM software shown below demonstrate how useful and easy to use the technology will be for architectural designers:

Step 1 (Figure 3). Build a simple 3D model in a gbXML compliant CAD tool (e.g., DesignWorkshop).

Step 2. Through the CAD tool's interface, specify the building's type and zip code, and auto-submit the file to GeoPraxis' EAM (www.GreenBuildingStudio.com).

Step 3 (Figure 4). View the energy analysis summary online or print to share with the client.

Step 4 (Figure 5). Email the geometrically accurate energy simulation model to your HVAC engineer or energy code consultant.

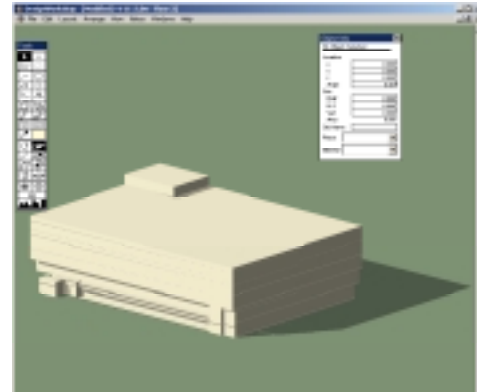


Figure 3: Rendering in DesignWorkshop

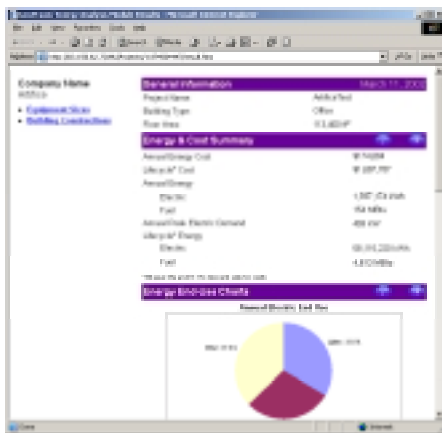


Figure 4. EAM Web Report

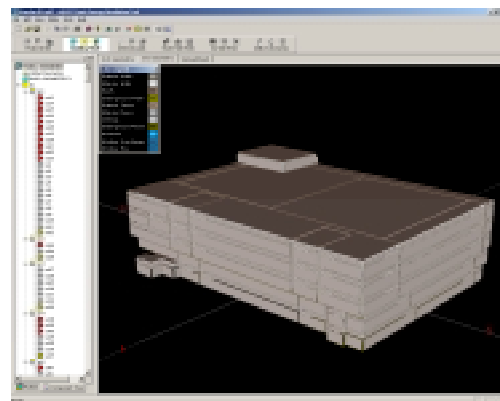


Figure 5. Same Model in eQUEST

Throughout the course of the project, GeoPraxis received countless comments in focus groups, surveys, and emails from architects, engineers, and other prospective end users of the EAM. While not all were supportive, the majority indicates that significant demand exists for an easy to use, CAD-interoperable energy analysis tool. The following collection of comments demonstrate that Objective #2 has been achieved²:

- “What would be helpful for me is a tool that would help do schematic design to give us ballpark figures, rather than like [at] 80% schematic to give it to the Title 24 guy to see that we’re way off. I mean, for me it [would be] like something that could help me get

ballpark figures through the very beginnings of the project. Especially for our residential projects, which is mostly what we do. That would be a lifesaver.”

- “I am always looking for productivity enhancements both for my firm and my clients. In particular, the blueprint takeoff is a time consuming and error potential cog in the wheel. I would love to get a system where we could scan prints not done in AutoCAD and/or directly take AutoCAD files and get 3-D volume based energy load calcs/ system sizing ...”
- “If this program is related to Title 24 Energy Compliance, I would use it on every project, because that’s the driving force – you run energy calcs on the building to make it comply. But if you have a program where you can try different strategies, then I would certainly be interested, because we always have someone else run the calculations and we just pray that it’s going to comply.”
- “If you are trying to do something new into the building design, then you have to do some research and study if time allows. It would be great if there were a tool that would help you analyze these things that you could simply plug in and do some numbers in a simple envelope. Just spit out at least some guidance that would help you go in that direction.”
- “We’ve tried many projects where we’ve introduced green, so-called green objectives, sustainable objectives, only to not have enough time to really evaluate the first costs, life cycle costs, paybacks, [it’s] schedules that are just so tight. Time is the constraint. It’s the worst enemy.”
- “It sounds like you’ve mirrored my wish list for a CAD interface for energy-engineering: a building geometry interface for sophisticated energy programs, like DOE [and] a universal protocol tying the AEC database to the building geometry. It’s that much better that you folks obviously care about creating green buildings, too.”

3.3 Objective 3: Demonstrate that the EAM is Affordable to Target Users

Clearly, the value of the EAM must be greater than its cost if it is to be adopted in any significant numbers by end users. Before discussing the project outcomes related to this objective, it is important to understand the present context in which building energy simulation analysis typically occurs and what the target population currently considers “affordable”.

Today, most whole-building energy simulation analysis is performed on a custom, per-project basis as a service provided by highly specialized energy engineers. To belong to this group, one must be familiar with at least one of the currently available analysis tools (e.g., Carrier HAP, Trane TRACE, eQuest/DOE2, Visual-DOE, Energy10). The engineer performs take-offs from the blueprints or CAD files, enters data into the software to build the thermal simulation model, runs the simulation to analyze various alternatives, and prepares a report to summarize the results. Of the many cases we encountered in our research, nearly all architects, building owners, and contractors told us they typically retain the services of one of these energy engineers rather than purchase the software and attempt to perform this process on their own. The going rate for this service runs anywhere from a minimum of about \$5,000 to as much as \$100,000 on large projects. As a California-based benchmark, the Pacific Gas & Electric “Savings by Design” new construction design assistance program offers this service to select non-residential customers at an average cost of approximately \$43,000 per project³. At this price, it is

no surprise how rarely this service is performed (less than 18% of all projects) – especially on smaller buildings (Air Conditioning and Technology Institute, 2002).

The CAD-interoperable EAM software makes significant productivity improvements possible by greatly reducing the amount of time required to do plan take-offs and build up the simulation model. GeoPraxis' own energy engineers report that even though it is still at the alpha stage, the EAM tool already cuts the time required to build an eQuest/DOE-2 simulation model in half.

Use of the EAM by subscription to the Green Building Studio ASP will cost some introductory users as little as \$200 to complete their first project. Within this context of current costs and potential productivity gains, this price represents a significant value. The following results from the "Willingness to Pay" questions (Table 1) included in the web survey further demonstrate that not only has Objective #3 been achieved, but that the service will be considered an excellent value².

Table 1. Web Survey Willingness to Pay Results (December 1999)

Web Survey Results: What would you pay?	All Architects. & Designers (n=282)		
	Mean	Median	Max
Price (Perpetual License)	\$ 470.43	\$ 300.00	\$10,000.00
Price (Monthly Subscription)	\$ 46.64	\$ 20.00	\$ 1,500.00
Price (Yr. Subscription; 12 X Mo.)	\$ 559.68	\$ 240.00	-
Price (Per Scenario)	\$ 89.33	\$ 50.00	\$ 1,500.00

3.4 Objective 4 Demonstrate that the EAM Can be Successfully Commercialized

Though the EAM is not yet commercially available to end users as originally planned, the following early indicators of market acceptance by other software developers indicate that this objective has been achieved:

- Artifice has devoted substantial programmer resources to develop the EAP and upgrade DesignWorkshop to prepare it for interoperability with the EAM using gbXML. Artifice is actively engaged in commercialization planning with GeoPraxis to ensure a timely return on this investment.
- The Trane Company, makers of the well-known HVAC analysis tool TRACE 700, has added to their program the ability to read in building geometry (spaces, surfaces, and openings) using gbXML files produced by the EAM. This allows their users a significant opportunity to save time and improve model accuracy by eliminating the redundant step of manual plan take-offs. A letter from the Trace product manager in support of ongoing gbXML and EAM R&D is included in Appendix III
- To enhance the value of the EAM to users who explained that code compliance was of paramount importance, GeoPraxis took the extra step of designing the EAM to be compatible not just with DOE-2 but with eQUEST. This increasingly well-known freeware interface to DOE-2.2, offered and maintained by JJ Hirsch and Associates, has

recently be coupled with a Title-24 code compliance rules set. Rather than attempt to replicate the functionality already available (for free) to users of eQUEST, GeoPraxis designed the EAM to take advantage of this market opportunity. Interoperability with eQUEST allowed GeoPraxis to focus the EAM on the needs of architecture-oriented users, while ensuring that engineering-oriented end users would be able to view and edit the many complex variables contained in the EAM's simulation models using eQUEST⁴. Compatibility with eQUEST is expected to be a major driver of EAM commercialization, at least until end users come to prefer DOE's new calculation engine, EnergyPlus.

- In June 2000, GeoPraxis demonstrated EAM gbXML-based interoperability with a beta version of EnergyPlus, DOE's next generation simulation engine. While significant end user demand for the unique capabilities of EnergyPlus has yet to develop, GeoPraxis has already demonstrated that the EAM will be able to transition to this new engine as soon as market conditions warrant and funding allows.
- Perhaps most significant of all, key members of the product and business development teams of all the leading CAD OEM vendors have indicated great interest in the results of the CDEAT project. Increasingly, A/E/C software providers have come to appreciate the benefits to becoming interoperable with downstream vertical applications (e.g., energy analysis, cost estimating, structural analysis, etc.) that leverage the model data originally contained in their CAD databases. Market leaders Autodesk (Architectural Desktop, Revit, Architectural Studio)⁵ and Bentley (MicroStation TriForma) have each registered to review the SDK. Representatives of both firms have also said they are preparing letters in support of the remaining R&D needed to bring the EAM to market. In addition, key personnel at Nemetschek (AllPlan, VectorWorks), Graphisoft (ArchiCAD), and @Last Software (Sketch Up) have indicated they will also be evaluating the project's accomplishments in the months ahead.

4.0 Conclusions and Recommendations

The major conclusions and recommendations of the CDEAT project are presented below.

4.1 Major Conclusions

Though there have been energy analysis tools developed for building designers in the past, there have not been any attempts to incorporate energy tools into a CAD tool to be used at the conceptual design phase. Based on the experience gained over the course of this project, we believe that our phased approach to software research and development and our early focus on interoperability, as well as market and technical research, has resulted in a tool that both meets users needs and can be readily integrated with other programs.

All of our market research confirmed some basic but powerful conclusions regarding market conditions and end-users' perceived needs:

- Ease of use is paramount
- Interoperability is vital to allow other design team members to share & improve the model as design progresses
- AutoCAD's file format constitutes the standard in the industry.
- 3D-CAD use is infrequent (approximately 10 to 15 percent of all projects), but growing steadily
- Users want to save time and money on design and product selection decisions
- Users also want relatively simple results; annual & lifecycle energy use & cost estimates; peak electric demand estimates; end use breakdowns; and to benchmark analysis results to code and "best practice."

The team's experience developing the EAM Software Specification, as well as the gbXML schema and SDK, led to the following conclusions:

- Individual software development firms (and their end users) will only benefit from the adoption of emerging software standards if the tools they develop are compatible with the standard. This makes standards development a highly political activity with significant business risks for developers of competing technologies and R&D investors who support them.
- Superior technical capabilities alone do not necessarily ensure market success for a given technology or technical standard. Success is more likely if a new technology (or standard) helps existing market players make money or enables new players to enter the market displacing existing players by delivering superior value to end users.

4.2 Commercialization Potential

The commercialization-related outcomes presented above demonstrate that CDEAT project has been a success and that the EAM has significant commercial potential if brought to market within the next 6 to 12 months. The Production Readiness Plan (Deliverable 2.8.2) outlined the Implementation Plan for completing the beta testing of the Artifice-linked EAM and launching the technology as an ASP on the Green Building Studio website. Outside the scope of the project deliverables, GeoPraxis has completed a great deal of market planning and business

development to support commercialization of the EAM. In addition to the upstream (CAD OEM) market participants mentioned above, GeoPraxis has and will continue to approach developers of other downstream applications that would benefit from interoperability with the EAM via gbXML. These include other leading HVAC analysis tools (Carrier HAP, CHVAC, etc.) and code compliance tools (EnergyPro, COMcheck-Plus, etc.)

GeoPraxis is actively seeking funding to complete the beta testing and launch the Green Building Studio from the California utility participants in the Emerging Technologies Coordinating Council (ETCC). ETCC was established to seek opportunities to coordinate efforts between each of the utilities' emerging technologies programs as well as the Commission's PIER program. Commission staff has been instrumental in suggesting this approach and getting these discussions started. Other private sources are also under consideration.

4.3 Benefits to California

Even at its outset, the CDEAT project had already begun generating economic and environmental benefits for Californians. Following GeoPraxis' incorporation in July of 1998, the PIER award for the CDEAT project in early 1999 was GeoPraxis' first major contract. As such, it constituted a significant endorsement for so new a firm. The financial stability the project afforded and the Commission's rigorous but even-handed contract management both helped greatly to build GeoPraxis into the successful small business it has become. In addition to the accomplishments described in this report, this success has allowed GeoPraxis to develop other market transforming technologies including the Time-of-Sale Home Energy Rating System (HERS) Server that has dramatically lowered the cost of producing a HERS rating for existing California residences.

While the significant forecasted energy and demand savings will not begin to accrue until the EAM is widely commercialized, already the EAM technology is being used in its alpha stage by GeoPraxis engineers to reduce the amount of time they spend conducting take-offs for new building design assistance projects. Rather than enter plan information into eQUEST/DOE-2 directly, the engineer builds a DesignWorkshop 3D-model, imports the model into the (soon to be integrated) EAP creating the mono-planarized gbXML file, and then submits the gbXML file to the online EAM. The resulting DOE2.2 file can then be read into eQUEST for detailed comparative energy engineering analysis. Though many steps are still involved at this stage of development, GeoPraxis engineers already report timesavings of 50% over conventional take-off data entry. GeoPraxis plans to test and use the technology in-house on several "Savings by Design" new construction design assistance projects currently being funded by Pacific Gas & Electric and Southern California Edison.

Based on these early results, the technology developed under the CDEAT project appears very likely to generate substantial economic and environmental benefits to California ratepayers in the years to come.

4.4 Recommendations

Recommendations for future action are organized below. First, actions GeoPraxis and its development partners should take are listed, followed by actions the Commission's PIER program should consider in its role as a supporter of energy-related research and development for the benefit of California. Finally, recommended actions by other parties are suggested.

- Recommended GeoPraxis Actions:
 - Complete the beta test of EAM interoperability with DesignWorkshop
 - Develop and launch the Green Building Studio (GBS) web site, a hosted application service provider for the EAM software
 - Support the GBS service launch with an integrated marketing campaign utilizing advertising, publicity, and events initially targeted to customers fitting the profiles of “green architectural designers” and “A/E/C CAD new technology enthusiasts”
 - Support the GBS service launch with a 0.5 FTE dedicated to technical support and customer service
 - Continue outreach and technical support to CAD OEMs and other application developers upstream of the EAM (to encourage implementation of gbXML export capabilities)
 - Continue outreach and technical support to OEM’s of HVAC analysis tools, code compliance tools, and other applications downstream of the EAM (to encourage implementation of gbXML import capabilities)
 - Continue to monitor and encourage progress in the development of software interoperability standards in the A/E/C industry; in particular to encourage interoperability between the standards developed in accordance with IAI’s Industry Foundation Classes (e.g., the BLIS initiative) and those proceeding under the IAI’s aecXML domain (e.g., the Building Performance and Analysis Working Group’s gbXML initiative)
 - Continue to augment GeoPraxis investments with funding from R&D sponsors, interested third parties, and private investors for ongoing enhancements to the EAM’s databases, simulation engines, and expert design decision assistance tools.
- Recommended Commission Actions
 - Maintain oversight of LBNL’s IFC-related activities (especially the BS-8 project) funded under PIER Building’s “Programmatic” Program to ensure those efforts don’t undermine but instead can take advantage of the CDEAT project’s commercialization achievements (e.g., interoperability with Trane TRACE using gbXML).
 - Expedite the review of JJ Hirsch Associates application to the Commission to certify eQUEST for use as a Title-24 compliance tool. This action would almost certainly increase the perceived value of the EAM to the large number of mainstream (i.e., minimally code-compliant) architectural designers practicing in California. In addition, this action would likely result in a significant increase in the number of California buildings subjected to hourly simulation analysis during the early stages of design.
 - Provide supplemental PIER funding to software developers to conduct EAM or gbXML-related research and development in those specific cases where the

proposed R&D meets the PIER program's objectives. Examples of R&D activities that are recommended over the next 2 years and which might meet PIER criteria include:

- Addition of gbXML-based interoperability to tools that are 1) already popular with California-based building designers (e.g. Architectural Desktop, MicroStation Triforma, ArchiCAD, VectorWorks, DataCAD, EnergyPro, MicroPas, etc.), or, 2) would be highly beneficial to California electricity ratepayers if more widely used in the design of California buildings (e.g., EnergyPlus, Carrier HAP, CHVAC, Lightscape, Radiance, WINDOW, COMIS, CONTAM, TRNSYS, FLUENT, FLOVENT, SkyCalc, etc.)
- Translation and publication in gbXML of the technical performance specifications of key high performance building products that are targeted for rebates and other commercialization assistance by California's energy efficiency (PGC) programs.
- Development of automated design decision assistance tools that save California architects time in researching and comparing the costs and benefits of high performance building products and design alternatives
- Continue to support GeoPraxis' efforts to secure additional funding, via ETCC, or other Federal, State or Private emerging technology assistance programs, to continue EAM R&D and commercialize the technology.
- Provide ongoing PIER funding to groundbreaking new building product and equipment technologies, the benefits of which might someday be introduced to building designers using gbXML-enabled energy analysis tools.
- Provide ongoing PIER funding to innovative market and behavioral research into the energy-related decision making practices of architects, engineers, contractors, building owners, and other groups so instrumental to the energy and resource efficiency of California's building stock.
- Continue to provide a preference in PIER awards for California-based businesses (particularly innovative small businesses like GeoPraxis) that generate immediate benefits (like new jobs in California) over large efforts involving many out-of-state and even international organizations where immediate benefits to California ratepayers may be hard to determine.
- Recommended Actions by Others
 - A/E/C 3D-CAD OEMs – Register and download the Software Developer's Kit and begin working with GeoPraxis and gbXML (www.geopraxis.com/content/eam_sdk.asp).
 - Building Products and Equipment OEMs – Contact GeoPraxis to learn how easy it is to publish high performance product specifications in gbXML.
 - 3D-CAD End Users - Register to find out when beta testing begins at www.greenbuildingstudio.com.

- Other R&D Organizations – Contact GeoPraxis to find out more about the CDEAT project and the next phase of planned research and development.

5.0 Endnotes

1. Climate data for several hundred international locations will be added soon.
2. Originally, the measurement of this objective was to have been accomplished by means of a survey of beta test participants.
3. \$1,000,000 allocated in 2002 to accommodate 23 projects (Pacific Gas & Electric, 2002).
4. At the CDEAT project Critical Review Meeting (April 15, 2002), GeoPraxis learned that eQUEST has been submitted to the Energy Commission for certification as a Title-24 compliance tool, with action expected within six months.
5. On April 2 2002, AutoDesk completed its acquisition of Revit Technology Corporation, a Massachusetts-based developer of parametric building technology for building design, construction, and management.

6.0 Glossary

ADT	Architectural Desktop - ADT is a 2D/3D-CAD architectural design/modeling software developed by AutoDesk, Inc
A/E/C	Pertaining to the building-related industries of Architecture, Engineering, and Construction
A/E/C FM	Pertaining to the building-related industries of Architecture, Engineering, and Construction and Facilities Management
aecXML	The aecXML schema is an XML vocabulary that is specific to A/E/C industries. It is a means of describing and sharing data with others in the A/E/C community, including: architects, engineers, contractors, owners/operators, estimators, consultants, materials suppliers, building product manufacturers, and others. One of the many features that makes aecXML so useful is its capacity to use existing software and databases to exchange information (http://www.iai-na.org/domains/aecxml.html).
aecXML BPA schema	aecXML's Building Performance & Analysis (BPA) - XML draft schema, maintained under the aecXML domain of the International Alliance for Interoperability. Also known as the gbXML schema administered by GeoPraxis at www.gbXML.org
ARTI	Air-Conditioning and Refrigeration Technology Institute - ARTI is a not-for-profit organization established in 1989 to undertake scientific research in the public interest. ARTI strives to be responsive to the research needs of the HVAC&R community with an emphasis placed on precompetitive investigations.
ASP	Application Service Provider - A model of software delivery where consumers pay a periodic fee in exchange for a license to use a specific software program that is hosted/maintained on a website (instead of on the end user's hard disk).
BLIS	Building Lifecycle Interoperable Software (http://www.blis-project.org/). BLIS is a coordination project -- coordinating the efforts of vendors seeking to support implementation of IFC specifications in software products

BS-8	<p>A project of the International Alliance for Interoperability (IAI). It is developing the Industry Foundation Classes (IFC) schemata for Heating Ventilation and Air-Condition (HVAC), and allows interoperability between building performance simulation tools. The project is based at the Building Technologies Department of the Lawrence Berkeley National Laboratory.</p> <p>(http://eetd.lbl.gov/btp/iai/bs8/) DesignWorkshop - Conceptual 3D-CAD architectural design/modeling software developed independently by Artifice, Inc</p>
Building	As defined by the EAM, a building is a collection of spaces and surfaces.
CAD	Computer-Aided Design
CADD	Computer-Aided Design/Drafting
Campus	As defined by the EAM, a campus is a collection of buildings that have some relationship to each other.
CIFE	Center for Integrated Facilities Engineering. Based at Stanford University, CIFE conducts research in the application of advanced technologies that will improve the productivity and quality of the AEC industry through increased automation and integration over the life cycle of a facility.
Client/Server Architecture	A network architecture in which each computer or process on the network is either a client or a server. Servers are powerful computers or processes dedicated to managing disk drives (file servers), printers (print servers), or network traffic (network servers). Clients are PCs or workstations on which users run applications. Clients rely on servers for resources, such as files (including applications), devices, and even processing power.
DesignWorkshop	A family of 3D modeling software tools developed by Artifice, Inc., designed to integrate with drafting software, on both Windows and Macintosh platforms (http://www.artifice.com/dw.html)
DLL	Dynamic Link Library, a library of executable functions or data that can be used by a Windows application.

DOE-2	An hourly, whole-building energy analysis program, developed by the Department of Energy, which calculates energy performance and life-cycle cost of operation (http://simulationresearch.lbl.gov/).
GUI	Graphical User Interface
EAM	Energy Analysis Module - EAM is the web-based energy analysis software developed by GeoPraxis, Inc., under the CDEAT project with funding from the California Energy Commission Public Interest Energy Research program.
EAP	Energy Analysis Preprocessor - The EAP is software developed by Artifice, Inc., to prepare DesignWorkshop files for energy analysis by the EAM and translate CAD data into gbXML format. The EAP was developed independently without PIER funding
ETCC	Emerging Technologies Coordinating Council - The ETCC was established under the auspices of the California Public Utilities Commission (Public Goods Charges) to seek opportunities to coordinate efforts between each of the California investor owned utilities' emerging technologies programs and the Commission's PIER program.
EnergyPlus	The Department of Energy's latest building energy simulation software program, EnergyPlus is a stand-alone simulation engine without a 'user friendly' graphical interface. It reads input and writes output as text files. Private sector companies (including GeoPraxis) are developing interfaces. (http://www.eren.doe.gov/buildings/energy_tools/energyplus/)
GBS	Green Building Studio is GeoPraxis' trademark for the ASP-based (www.greenbuildingstudio.com) CAD file processing service that will host the EAM software. GeoPraxis will license the GBS website functionality to resellers under other brands (e.g., CAD software OEM's, A/E/C project management extranets, etc) and will offer subscriptions to the service direct to end users of bXML-compatible CAD software programs.
gbXML	GreenBuilding XML data files are XML files, the structure of which is defined by the GreenBuildingXML Schema

	http://www.gbxml.org). gbXML is also known as aecXML's Building Performance & Analysis (BPA) XML schema.
HVAC	Heating, Ventilation, and Air-Conditioning
HTML	Hyper Text Markup Language, the authoring language used to create documents on the World Wide Web.
IAI	The International Alliance for Interoperability - The IAI's mission is to allow interoperability among work processes in the AEC industry by enabling all participants' computer applications to share and exchange project information through entire project lifecycle (strategic planning, design, engineering, construction, operation). (http://www.iai-international.org/iai_international/). IAI has recently been absorbed as a council of the National Institute of Building Sciences.
IFC	Industry Foundation Classes - A cross-platform, vendor-neutral standard, developed by the IAI, that allows architectural CAD users to transfer a complete, thorough, and accurate building data model from one CAD platform to another, with no loss of data
Interoperability	The ability of computer applications to share and exchange project information. In order for data transfer to work properly there needs to be an agreement on definitions of data. Two such exchange formats for buildings-related data currently exist: aecXML and IFCs
LBNL	Lawrence Berkeley National Laboratory (http://www.lbl.gov/) - LBNL is host to the Simulation Research Group and is involved in the BS-8 project of the International Alliance for Interoperability (IAI).
Mono-planar model	As defined by the EAM, the mono-planar model is a model of a building composed of planar surfaces that represent the actual volumetric elements of the building.
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer

Opening	As defined by the EAM, an opening is a large penetration in a surface where a window, skylight, or a door may fit. An opening can also have nothing in it except air.
Plug-in	A hardware or software module that adds a specific feature or service to a larger system. For example, there are number of plug-ins for the Netscape Navigator browser that enable it to display different types of audio or video messages
SDK	Software Developers Kit - The SDK for GeoPraxis' EAM now includes: 1) the general development requirements needed to support the EAM, 2) the minimum gbXML elements that must be supported, 3) additional elements that may be supported to extend EAM functionality, 4) the EAM Application Programming Interface (API), 5) EAM object rules, 6) a discussion of simulation model development and model reduction theory, 7) a list of EAM components, and 8) a glossary. The SDK can be downloaded from GeoPraxis' website (http://www.geopraxis.com/content/eam_sdk.asp).
SOAP	Simple Object Access Protocol (http://www.w3.org/TR/SOAP) - SOAP is a protocol for exchanging information. It is typically used to allow program functionality over the Internet in a cross-platform manner. Free client-side applications are available for CAD developers to use on most operating systems.
Space	As defined by the EAM, a space is a volume enclosed by many surfaces that is used as a room in a building.
Surface	As defined by the EAM, a surface is an opaque planar polygon that represents interior and exterior walls, ceilings, floors, slabs, roofs, and other opaque diaphragm type structures in a building.
TRACE	A software program developed by The Trane Company (a manufacturer of HVAC equipment) that models buildings, HVAC systems, and economic/utility scenarios. (http://www.trane.com/commercial/software/trace/)
VAR	Value-Added Reseller

VRML

Virtual Reality Modeling Language, a specification for displaying 3-dimensional objects on the World Wide Web. It is often described as the 3-D equivalent of HTML.

XML Schema

XML Schema (<http://www.w3.org/XML/Schema>) is an XML language that defines the structure of XML documents.

XML

Extensible Markup Language (<http://www.w3.org/XML>) - XML is a format for structured data. XML is platform-independent and is in plain text. XML is similar to HTML, except that tags are customized for a specific application. Tag names and format of this data can be defined using XML Schema language

Zone

As defined by the EAM, a zone is a collection of one to many spaces that are cooled or heated by the same system under the same control. Generally the combined spaces have the same type of thermal loads and operation schedules.

7.0 References

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Appendix I
Focus Group Results and Analysis Report

Appendix II

Design Methods Survey Summary Report

Appendix III
Letters in Support of Additional EAM and gbXML R&D

Appendix IV
Tri-fold Project Summary Brochure



DesignCommunity.Com Design Methods Survey Summary Report

Image: GreatBuildings.Com © Artifice, Inc.



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INTRODUCTION

This report presents the results of the DesignCommunity.Com web-based survey of building design professionals. The survey was launched on October 8, 1999 and completed on December 7, 1999. The survey was collaboratively designed and conducted by GeoPraxis and CAD developer Artifice Inc.¹, with the generous financial support of the California Energy Commission's Public Interest Energy Research (PIER) Program, and additional support by The American Institute of Architects, and DesignCommunity.Com.

The web-based survey was an unqualified success attracting 774 interested respondents and 419 eligible participants from 32 countries. This high level of participation was made possible by diligent efforts to publicize the survey and the power of the Internet to accelerate the transmission of popular ideas. We are greatly appreciative of the individual time and attention contributed by each of these many survey participants.

Announcements of the CAD survey (and PalmV sweepstakes) were placed on a large number of online news groups and websites frequented by architects and other building design professionals. Key among these was GreatBuildings.Com, perhaps the most frequently visited architecture site on the Web. (According to Alexa visitor statistics², it receives more than ten times the combined traffic of the websites of Architectural Record, Architecture, and Architectural Review.) In addition direct email solicitations were made to AIA members listed in the AIA/CMD ProFile database and registered downloaders of the free version of the CAD tool DesignWorkshop. Finally offering an invaluable implicit endorsement of the survey, the AIA's Director of Professional Practice emailed announcements to members of the AIA's Committee on Computer-Aided Practice and Committee on the Environment.

A conscious attempt was made to attract respondents with a pre-existing interest in "green building design" and "the energy performance of buildings". These issues were made prominent in the announcements circulated. The announcement on the following page greeted all those who visited the survey.

¹ Artifice is the maker of the 3D CAD tool DesignWorkshop® and operates the DesignCommunity.Com and GreatBuildings.Com websites.

² The Artifice family of architecture-related web sites generates more than 2,000,000 monthly page impressions, with 100,000 weekly visitors.

SURVEY ANNOUNCEMENT

DesignCommunity Fall 1999 Design Methods Survey

* [Take The
Survey Now](#) *

If you're an eligible 3D CAD user, please take this online survey – you'll automatically be entered in our drawing for a Palm V™ organizer!



[Available at Amazon.com](#)

With the support of the [California Energy Commission](#) and CAD developer [Artifice, Inc.](#), the resource engineering firm [GeoPraxis Inc.](#) is developing an easy-to-use, energy analysis software module that will be integrated with existing 3D CAD architectural software tools.

This exciting new desktop energy tool will allow building designers to quickly compare design alternatives, and easily estimate the energy performance of a building, while the project is still in the schematic or conceptual phase of design.

Many experts agree that this new tool will help create greener, more energy efficient buildings — without adding to the overall cost of the design process — leading to significant energy savings nationwide. For more information about the project, visit www.geopraxis.com/cec.htm.

To ensure the success of this project we are seeking input from architectural 3D CAD users, in the form of a Design Methods Survey. We want your practical input on how to configure this new kind of software so that it will meet the needs of designers in the real world. If you use 3D CAD tools for architectural design, we invited you to help us advance the state-of-the-art by answering our online survey... and if you entered, you might just win a very cool [Palm V™](#)!

Follow this link for more information about the [Fall 1999 Design Methods Survey](#). Every qualified respondent who completed the survey is automatically entered to win!

SURVEY SAMPLING

With the web survey, we were not seeking to draw a representative sample of all firms practicing architecture in California or the United States and these results should not be expanded to this population at large.³ Instead our focus was on the opinions and practices of the subset of "target users" who are most likely to be the early adopters of the 3D CAD Energy Analysis Module (EAM) software tool currently under development by GeoPraxis. For this reason we limited participation in the survey to building design professionals who have personal experience in the use of 3D CAD. The list of qualified positions included:

- Developer
- General Contractor
- Engineer Designer
- Licensed Engineer
- Architectural Designer
- Registered Architect
- Interior Designer
- Lighting Designer
- CAD Drafter
- CAD Manager

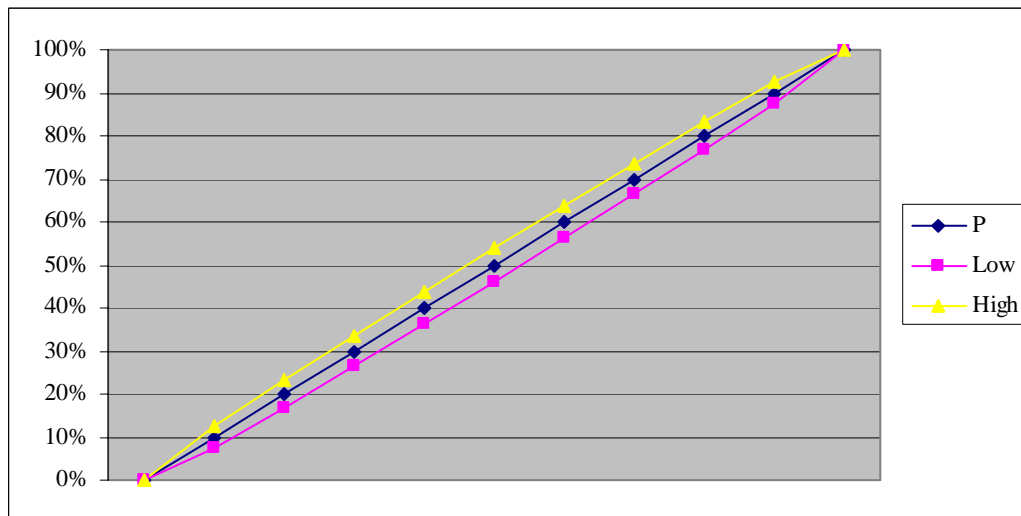
Based on our analysis of the population of professional architects in California (Web Survey Sample Design Memo D2.1.4) we hypothesized that if the use of CAD were to be evenly distributed throughout the population of design professionals, then roughly 60% of our responses would come from firms whose projects are primarily in the residential sector (>80% of projects residential). The remaining 40% we expected would come from firms who work either primarily on non-residential projects (>80% commercial and/or institutional) or work on a truly mixed group of projects.

In fact we found that CAD use appears to be much more common among designers of commercial buildings. Fully half (50.1%) of our qualified respondents reported that 80% or more of their projects are in the commercial sector. Of the remaining half of our sample, only 19.8% are focused primarily on the residential sector (>80% of projects residential) and the remaining 30.1% work on a more balanced mix of projects.

If we accept the self-selection bias that is inherent to our explicit decision to focus on the "target users" niche, we estimate the survey describes this sub-population with a statistical precision of +/- 4.0% (90% confidence).

³ See the July 29 memo to the CEC on "Rationale for changes to CDEAT end user survey" for a detailed discussion of the web survey objectives, and alternative sources that contain representative data on architectural practices in CA and nationwide.

Estimated Statistical Precision of the Design Methods Survey Overall				
Survey Estimate	Standard Error	Error Bound	Low Estimate	High Estimate
0%	0	0.0%	0.0%	0.0%
10%	0.015	2.4%	7.6%	12.4%
20%	0.020	3.2%	16.8%	23.2%
30%	0.022	3.7%	26.3%	33.7%
40%	0.024	3.9%	36.1%	43.9%
50%	0.024	4.0%	46.0%	54.0%
60%	0.024	3.9%	56.1%	63.9%
70%	0.022	3.7%	66.3%	73.7%
80%	0.020	3.2%	76.8%	83.2%
90%	0.015	2.4%	87.6%	92.4%
100%	0	0.0%	100.0%	100.0%



Graphical Representation of Statistical Precision

CHARACTERISTICS OF RESPONDENTS

Professional Background

Of the 419 total respondents who completed the survey, 78 percent were architecture professionals (Registered Architects 42%; Architectural Designers 36%), 10 percent were Developers, and 7% preferred the title "CAD Drafters". The remaining 5 percent were Contractors (1.7%), Engineers (1.0%), Interior Designers (1.7%) and Lighting Designers (0.2%).

Geographical Representation

Survey responses were collected from 30 countries, however the vast majority (90%) of these were from North America. The United States delivered 88.5% of all survey respondents, followed by Canada (1.4%).

The States most prominently represented include California (20%), Texas (4.5%), Oregon (4.5%) Pennsylvania (4.3%), and New York (3.8%).

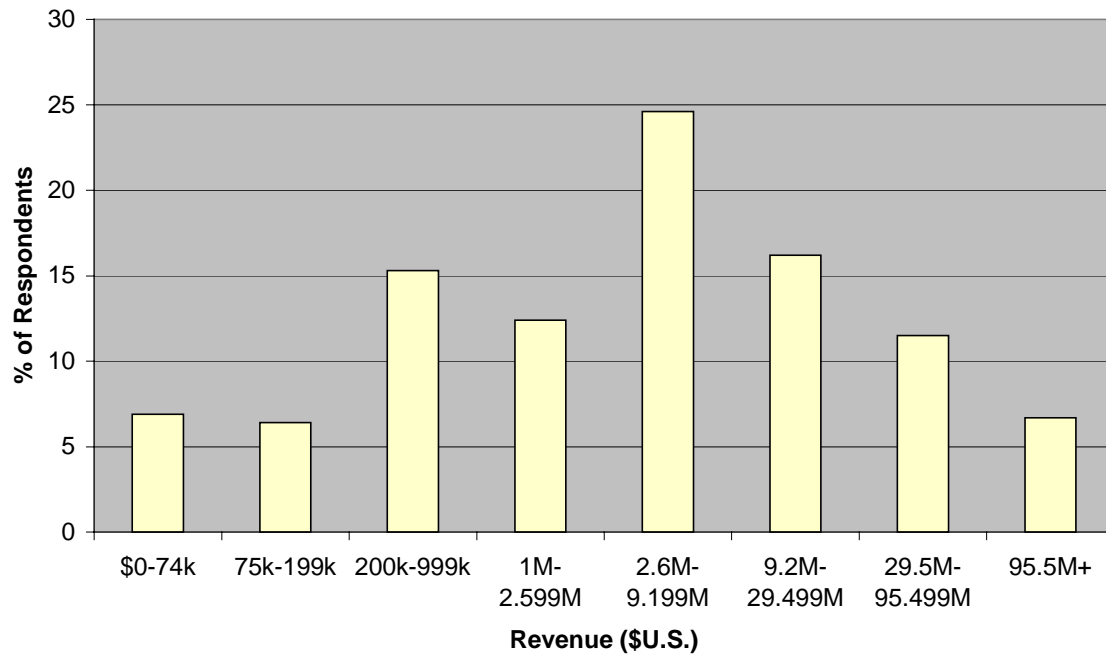
Scale of Firms and Projects

The average number of employees per firm was 74, and the largest firm represented employed 2,400 people.

Largest Project in 1998	
(Total construction cost, including design fees, excluding site acquisition costs)	
Revenue (\$U.S.)	%
\$0-74k	6.9
75k-199k	6.4
200k-999k	15.3
1M-2.599M	12.4
2.6M-9.199M	24.6
9.2M-29.499M	16.2
29.5M-95.499M	11.5
95.5M+	6.7
Total	100.0

Firms that work on a variety of project sizes are represented in the data. The table above indicates that the largest projects of over 41% were less than \$2.6M in 1998. However a number of sizable firms are also well represented. The chart below graphs the distribution of these largest projects data.

Largest Project in 1998



SURVEY RESULTS

Usage of 3D Modeling Tools in the Design Process

Over 68 percent of the respondents report they always (27%) or frequently (41%) use a "simple" 3D CAD model early in their new construction design process. Some 30% "occasionally" use a simple model in the early phase of design while 2% "never" do.

In contrast only 44 percent report they always (14%) or frequently (30%) use "simple" 3D CAD models late in the design process. Just over 46% "occasionally" use a simple model in the late phase of design while 9% "never" do.

The use of detailed 3D modeling is less common. Only 29 percent report they make regular use of a "detailed" 3D CAD model early in design (21% "frequently" and 8% "always"). The majority (50%) only "occasionally" use a detailed model in the early phase of design while almost one in four (22%) "never" do.

However detailed modeling is more popular late in the design process. Just over 42 percent always (14%) or frequently (29%) use a "detailed" 3D CAD model late in the design process.

In summary, for new construction projects, over two-thirds of the respondents said they use a "simple" 3D CAD model early in their design process, whereas, less than a third use a "detailed" 3D CAD model early in their design process.

Respondents were asked what percentages of their projects are taken to various levels of presentation using 3D CAD. Mean scores across the entire sample are reported in the table below. Basic Computer-Rendered Stills are used most commonly on an average of 44% of all projects. On average, this group does not use 3D CAD at all on roughly 31% of its projects. This indicates that over two-thirds of this group's projects receive some form of CAD-assisted presentation.

Levels of 3D CAD Assisted Presentation	Mean %
Basic Computer-Rendered Stills	44%
Photorealistic Computer-Rendered Stills	25%
Recorded Walkthrough Animation	8%
Live Walkthroughs	6%
3D CAD not used for Presentation	31%

Firm-Level CAD Use

Overall CAD Tool Use

The CAD tools being used overall at the firms of survey respondents are shown below. For this question, respondents were allowed to list multiple products, including both 2D and 3D tools. AutoCAD R14 followed by its successor AutoCAD 2000 are clearly the most widely used products.

Overall CAD Tools Used		
Rank	Program	%
1	AutoCAD R14	58
2	AutoCAD 2000	31
3	3D Studio VIZ	29
4	Architectural Desktop	25
5	3D Studio MAX	23
6	Form Z	22
7	Accurender	15
8	AutoCAD LT	15
9	MicroStation	15
10	ArchiCAD	14
11	DesignWorkshop	12
12	Auto-Architect	9
13	VectorWorks	9
14	DataCAD	8
15	MiniCAD	8
16	TriForma	6
17	PowerCAD	6
18	AutoCAD R12	6
19	AutoCAD R13	6
20	IntelliCAD	5
21	TurboCAD	4
22	Arris	3
23	All Other (those under 3%)	28

Most Extensively Used Single CAD Tool

The top nine CAD tools being used singularly and most extensively at the respondents' firm are shown below. Respondents were only allowed to choose a single tool to answer this question. While AutoCAD R14 is still the dominant product, ArchiCAD displaces AutoCAD 2000 for second place.

Single CAD Tool Used Most Extensively		
Rank	Program	%
1	AutoCAD R14	36
2	ArchiCAD	8
3	AutoCAD 2000	8
4	Architectural Desktop	7
5	MicroStation	5
6	VectorWorks	5
7	PowerCADD	4
8	DataCAD	4
9	AutoCAD LT	3
10	All Other (those under 3%)	19

Overall CAD Tools Used specifically for 3D Modeling

The top ranked CAD tools being used specifically for 3D modeling at the respondents' firm are listed below. Again, for this question, respondents were allowed to list multiple tools.

Overall CAD Tools Used for 3D Modeling		
Rank	Program	%
1	AutoCAD R14	35
2	3D Studio VIZ	26
3	3D Studio MAX	22
4	Form Z	18
5	Architectural Desktop	18
6	AutoCAD 2001	15
7	Accurender	11
8	ArchiCAD	11
9	DesignWorkshop	11
10	MicroStation	8
11	VectorWorks	7
12	Auto-Architect	6
13	DataCAD	5
14	TriForma	5
15	AutoCAD LT	3
16	MiniCAD	3
17	All Other (those under 3%)	11

While AutoCAD R14 continues to dominate, the most popular 3D specialty tools (3D Studio Viz, 3D Studio Max, and FormZ) appear near the top of the list. Only 11% use some other 3D-modeling tool not listed in the extensive list the survey provided.

Most Extensively Used 3D Modeling CAD Tool

The top CAD tools being used most extensively and specifically for 3D modeling at the respondents' firm are shown below. While AutoCAD R14 remains the favorite, the next six ranked products are locked in a battle for second place in this emerging market separated by no more than two percentage points (i.e., a statistical dead heat).

Single CAD Tool Used Most for 3D Modeling		
Rank	Program	%
1	AutoCAD R14	17
2	3D Studio VIZ	9
3	Form Z	9
4	Architectural Desktop	8
5	3D Studio MAX	8
6	ArchiCAD	8
7	DesignWorkshop	7
8	VectorWorks	5
9	AutoCAD 2000	4
10	DataCAD	4
11	MicroStation	3
12	All Other (those under 3%)	20

Of the extensive list the survey provided, Autodesk products were reported being used as the preferred (most extensively used) tool for 3D modeling just under half the time.

Autodesk Market Share-3D Modeling	
Program	%
AutoCAD R14	17
3D Studio VIZ	9
3D Studio MAX	8
Architectural Desktop	8
AutoCAD 2000	4
AutoCAD LT	1
AutoCAD R12	1
AutoCAD R13	1
Total	49

Overall Effectiveness Rating of 3D CAD Tool Use in Firm

Respondents were asked to rate the "overall effectiveness of 3D CAD use in your firm, relative to the most effective current usage you can imagine" on a scale of 1 – 7 ("1" being "not effective at all" and "7" being "most effective").

Only 27 percent rated the overall effectiveness of 3D CAD usage in their firm a "6" (12%) or a "7" (15%). Across the board the average rating was 4.52. Almost a third (29%) of those surveyed are disappointed with 3D CAD implementation in their firm assigning a low score of "3" (18%), "2" (9%) or "1" (2%).

Individual CAD Use

CAD Tools Used for 2D Drawing/Drafting

The most frequently mentioned CAD tools personally used by the respondents in performing 2D drawing/drafting tasks are shown in the table below. Following AutoCAD products R-14 and 2000, Bentley's Microstation makes its way into third place.

Programs Used for 2D Drawing/Drafting		
Rank	Program	%
1	AutoCAD R14	48
2	AutoCAD 2000	21
3	MicroStation	9
4	AutoCAD LT	9
5	VectorWorks	7
6	PowerCADD	5
7	DataCAD	5
8	MiniCAD	5
9	All Other (those under 3%)	20

Most users have already abandoned earlier AutoCAD products (i.e. AutoCAD R12 and AutoCAD R13). These two represented only 5 percent combined. Also, ArchiCAD and Architectural Desktop are evidently not being used for 2D drawing/drafting.

CAD Tools Used for 3D Modeling

The top ranked CAD tools used most often by each respondent for 3D modeling tasks are shown in the table below. Again, AutoCAD R-14 remains far ahead of its closest competitor, FormZ. After AutoCAD 2000, DesignWorkshop makes its most respectable showing yet used by 9% of those surveyed.

CAD Tools Used Currently for 3D Modeling Tasks		
Rank	Program	%
1	AutoCAD R14	32
2	Form Z	12
3	AutoCAD 2000	10
4	DesignWorkshop	9
5	VectorWorks	6
6	MicroStation	5
7	TriForma	4
8	DataCAD	4
9	All Other (those under 3%)	20

Frequency of 3D CAD Tool Usage

Of all those surveyed, 23 percent say they use a 3D CAD tool every day, another 21% use one at least 3 days a week, and 20% use one at least once a week. Therefore a total of 64 percent use a 3D CAD tool at least once a week. Just over 15% use a 3D CAD tool less than once a month.

Satisfaction with 3D CAD Tool Usage

Respondents were asked to rate "how well your needs are met by the 3D CAD tools you are currently using" on a scale of 1 – 7 ("1" being "Totally Unsatisfied" and "7" Very Satisfied").

Only 28 percent rated the overall effectiveness of 3D CAD usage in their firm a "6" (18%) or a "7" (10%). Almost a quarter (23%) of those surveyed are dissatisfied with how the 3D CAD they use meets their needs assigning a low score of "3" (16%), "2" (5%) or "1" (2%). The overall mean score was 4.66.

Energy Code Compliance and Energy Analysis

Respondents report that as a group, about 18 percent of their projects receive no code compliance energy analysis. At the other end of the spectrum, 27 percent stated that all their projects receive energy analysis for code compliance. The remainder fall somewhere in between.

Over 41 percent report that their firms never do any more energy analysis than code requires. Another 25% go beyond code on just 10% of their projects and 8% more say they exceed code on 20% of their projects. Therefore fully three-quarters agree that exceeding code is very rare. On the other hand, a committed 5 percent of those surveyed say they "Always" go beyond what is required for code compliance – studying energy alternatives on every job. This latter group is believed to be the population already most familiar with the current generation of energy analysis tools.

When projects need advanced energy analysis, over two-thirds (68%) reported they go to an outside consultant for these analytical services. The remaining 32% perform this analysis in-house.

The average cost for "advanced energy analysis" on a typical project was estimated to be \$3,475. It can cost as much as \$50,000 to \$100,000 on typical projects for the larger firms. Out of all of the respondents, 18 percent said the cost for these services was zero (presumably, these are estimates for in-house analysis and exclude transaction costs and overhead). These zero values are therefore likely to be lowering the overall mean and suggest that the estimate of \$3,475 should be considered conservative.

Construction Project Type Comparisons

Questions about specific types of construction projects were administered to subsets of the sample depending on how they had characterized the bulk of their firm's projects (">80% residential"; ">80% Commercial"; or "Mixed") in an earlier question. The following table describes how often the respondents reported having at least some experience working on specific types of construction projects.

These results indicate a wide range of diversity in the collective project experience of the survey respondents. Residential Tract construction was the least familiar to the sub-group we surveyed on this project type (>80% Residential), but still almost two-thirds of this group had worked on tracts.

Type of Project	Subset	%
Residential Tract	>80% Res.	63
Residential Custom	>80% Com. ⁴	86
Small Spec. Retail/Office	>80% Comm. & Mixed	91
Mid-size design/build	>80% Comm. & Mixed	86
Large Govt. or School	>80% Comm. & Mixed	84

The table below presents a summary comparing the design practices that our respondents told us are conventional for various typical construction project types.

Construction Projects					
1	2	3	4	5	6
Project Type	Avg. # Days	< 1 day E design	No 3D	Detailed	Rendering
Residential Tract	8.7	83%	15%	31%	49%
Residential Custom	12.6	62%	13%	44%	60%
Small Speculative Retail/Office	12.2	81%	15%	30%	61%
Mid-Size Design/Build	22.1	72%	14%	34%	66%
Large Government/School	39.4	45%	13%	49%	71%

Column #1 lists the various project types we asked people to consider. The second column records the average number of days each type of project takes to complete the conceptual design phase (residential tracts go fastest while large public sector projects take the longest). The third column indicates the cumulative percentage of respondents who reported that any energy and environment-related design considerations took less than one day to complete. The fourth column shows the percentage of respondents who said they wouldn't use 3D CAD during the conceptual design of such a project. Column #5 shows how many said they would use a 3D CAD "Detailed Model" during the conceptual design of such a project. Finally, the last column shows how many said they would use 3D CAD "Presentation Renderings" during the conceptual design of such a project.

⁴ An inadvertent error in the programming of the survey screens apparently required respondents who indicated that their firms projects were ">80% Commercial" to answer the questions regarding Custom Homes. Even so, 86% had experience with this type of project.

User Interface Preferences

Respondents were shown illustrations of two possible interface alternatives and asked "For the task of specifying attribute data for several or more graphic objects in a building model, which type of interface would you prefer. Almost 73% reported they would prefer to use a "Floating Window" feature to a tabular "Matrix" feature (27%) for specifying attributes. This finding suggests that users initially dislike spreadsheet-like input screens even though we believe that experienced program users who get past this preference will ultimately find them faster and easier to use.

In addition, 84% reported they would use a "Wizard type step-by-step interface" at least "Sometimes". Almost half (47%) believe they would use this method a lot ("Frequently" 47%; "Always" 9%).

Perceived Value of the EAM Tool

Almost 86 percent are at least "Somewhat Interested" in purchasing accessory software for their current primary 3D CAD program that could provide a fairly accurate prediction of building energy and environmental performance. Of these, over 40 percent are "Very Interested" and 45 percent are "Somewhat Interested". In contrast, only 2 percent of those who completed the survey are "Not at all Interested". This suggests very strong market demand for this kind of product among the niche we surveyed.

This finding may be particularly significant to makers of competing 3D CAD products. Some 30 percent said they would be at least somewhat interested in switching 3D CAD products in order to use the accessory software ("Very Interested" 6%; "Somewhat Interested" 25%). A loyal group of 31% said they are "Not at All Interested" in switching to access the EAM.

Web-based delivery is also particularly appealing to the respondents. Eighty-four percent said they would be at least "Somewhat Interested" ("Very Interested" 35%; "Somewhat Interested" 48%) in submitting their "conceptual design phase 3D model to an interactive web site that would provide a fairly accurate analytical prediction of building energy consumption". Only 6% are "Not at All Interested" in using such a website to access the EAM.

The perceived value of such an accessory tool is relatively high. The average price the respondents stated they would be willing to pay is \$455. Interestingly, Internet pricing preferences are also quite respectable. The respondents indicate they would be willing to pay \$50/month or \$100 per scenario to access these features over the Internet.

These findings suggest a viable commercialization opportunity for the CAD EAM. These data should provide a compelling rationale for other CAD developers to consider integration with the EAM.

APPENDIX

Tabular survey results (SPSS 10.0 output) are contained in the appendix to this report. Questions regarding the survey methods or findings should be directed to Tom Conlon, GeoPraxis (tconlon@geopraxis.com).

Appendix III
Letters in Support of Additional EAM and gbXML R&D



June 10, 2002

Re: Support for New Research on gbXML-based CAD/Energy Analysis Interoperability

To Whom It May Concern:

As a representative of Bentley Systems, Inc., a worldwide leading provider of engineering software in the Architectural/Engineering/Construction/Facility Management (AEC/FM) industry, I am writing in support of further research and development into some promising new information technologies of great value to our industry. These technologies are the Green Building XML (gbXML) schema and the CAD Energy Analysis Module (EAM) software developed by GeoPraxis, Inc. These technologies were developed under the Conceptual Design Energy Analysis Tool (CDEAT) Research and Development Project with funding provided by the California Energy Commission's Public Interest Energy Research (PIER) Program.

gbXML and the GeoPraxis EAM function together to form a critical design-data bridge between architects and other "downstream" design team members responsible for engineering, energy-code compliance, and ultimately building operations and maintenance. Based on our preliminary review of these technologies, I am excited about the potential this brings to our industry and the ability to link them with our existing CAD applications. The fundamental difference between these applications vs. other analysis platforms is that unlike current energy simulation software tools that require substantial time, cost, and expertise to use, this technology will conceivably lower costs to a level where many more design professionals will be able to make this type of sophisticated energy analysis available to their clients. Providing analysis tools such as this virtually insures that the percentage of building analysis performed in initial design will dramatically increase. We find that as fees continue to dwindle and profit margins continue to fall on new construction, prime contractors continually look for ways to cut costs; unfortunately comprehensive load calculations and consumption studies tend to suffer the brunt of design cuts. Providing a more intuitive, less costly means of performing these studies opens the door for many more professionals to offer this service.

I would like to encourage the California Energy Commission and other organizations interested in advancing research and development in the AEC/FM "interoperability" area to continue to build on the initial success of the CDEAT R&D Project. I strongly recommend that supplemental funding be provided to GeoPraxis in an amount that is adequate for further development of other CAD data bridges and to complete beta testing to ensure its successful commercialization in the AEC/FM industry.

I would be happy to discuss this matter further as may be necessary.

Sincerely,

A handwritten signature in cursive script that reads 'Duane A. Barrett'.

Duane A. Barrett
Product Manager, HVAC Applications
Former Vice Chairman, ASHRAE TC1.5 Computer Applications

Re: Support for New Research on gbXML-based CAD/Energy Analysis Interoperability



To Whom It May Concern:

As a representative of Trane, a provider of HVAC energy analysis software in the Architectural/Engineering/Construction/Facility Management (AEC/FM) industry, I am writing in support of further research and development into some promising new information technologies of great value to our industry. These technologies are the Green Building XML (gbXML) schema and the CAD Energy Analysis Module (EAM) software developed by GeoPraxis, Inc. These technologies were developed under the Conceptual Design Energy Analysis Tool (CDEAT) Research and Development Project with funding provided by the California Energy Commission's Public Interest Energy Research (PIER) Program.

gbXML and the GeoPraxis EAM function together to form a critical design-data bridge between architects and other "downstream" design team members responsible for engineering, energy-code compliance, and ultimately building operations and maintenance. Based on our preliminary review of these exciting new technologies, I believe they have greater potential than other previous technologies with which I am familiar to lead to viable commercial products that will substantially lower the cost of conducting energy analysis at the conceptual stage of building design. Unlike current energy simulation software tools that require substantial time, cost, and expertise to use, this technology will conceivably lower costs to a level where many more design professionals will be able to make this type of sophisticated energy analysis available to their clients.

I would like to encourage the California Energy Commission and other organizations interested in advancing research and development in the AEC/FM "interoperability" area to continue to build on the initial success of the CDEAT R&D Project. I strongly recommend that supplemental funding be provided to GeoPraxis in an amount that is adequate to complete beta testing and prepare this promising emerging technology to ensure its successful commercialization in the AEC/FM industry.

I would be happy to discuss this matter further as may be necessary.

Sincerely,

Wes Drye
Project Manager TRACE™ 700
Trane

"This technology will conceivably lower costs to a level where many more design professionals will be able to make this type of sophisticated energy analysis available to their clients".

- Wes Drye The TRANE Company

GREEN BUILDING STUDIO

End users of gbXML-compliant CAD software will have the option of subscribing to GreenBuildingStudio.Com, where they can use the EAM software and model processing service as a hosted ASP application. GeoPraxis will also license Green Building Studio technology for branding and integration by other software or service providers.

Green Building Studio will begin beta testing in the Fall of 2002.

HOW TO GET INVOLVED

A/E/C 3D-CAD OEMs – Register and download the Software Developer's Kit and begin working with GeoPraxis and gbXML (www.geopraxis.com/content/eam_sdk.asp).

Building Product OEMs – Contact GeoPraxis to find out how easy it is to publish your performance specifications in gbXML.

3D-CAD End Users - Register to find out when beta testing begins at www.greenbuildingstudio.com.

R&D Organizations – Contact GeoPraxis to find out more about the CDEAT project and the next phase of planned research and development.

The CDEAT project was begun in 1999 under funding from the California Energy Commission's Public Interest Energy Research (PIER) Program. The PIER Program supports research and development that will help improve the quality of life in California by bringing affordable, environmentally safe, and reliable energy services and products to the marketplace.



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CONCEPTUAL DESIGN ENERGY ANALYSIS TOOL

R&D PROJECT SUMMARY

*Making CAD / Energy
Analysis Interoperability a
Reality*



Image: www.Greatbuildings.com © Artifice, Inc.

PROJECT OVERVIEW

Building designers have long dreamed of being able to easily estimate the energy performance of a building without having to become expert users of complex engineering software.

The goal for the Conceptual Design Energy Analysis Tool (CDEAT) project was to develop a commercially viable software tool that would enable architects and developers to estimate a building's energy usage and cost during the early stages of architectural design.

R&D OBJECTIVES

1. Design and develop the Energy Analysis Module (EAM) software
2. Demonstrate that the EAM is useful, credible, and affordable to 3D-CAD users, and can be commercialized.

MAJOR ACCOMPLISHMENTS

- gbXML– an open data format for sharing architectural CAD data with energy analysis, facility management, and other downstream applications
- EAM – an easy-to-use web-based energy software tool that provides a quick estimate of energy use and cost and automatically creates a robust simulation model to share with other design team members
- SDK – a Software Developers Kit to help CAD firms implement gbXML
- Demonstrated EAM interoperability with DesignWorkshop (3D CAD) and energy tools: TRANE Trace 700, eQuest/DOE-2, and EnergyPlus (Beta).

gbXML

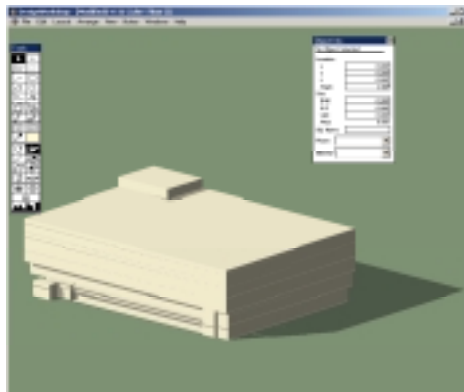
Green Building XML (gbXML) is the key to sharing data between 3D-CAD and energy simulation software (www.gbxml.org). Based on Extensible Markup Language (XML), gbXML is the draft schema for the IAI-aecXML Building Analysis & Performance working group.

Developers of advanced 3D-CAD tools will usually require much less time to integrate gbXML than other more complex data formats. The same is true for downstream applications that can use CAD data.

“If it fits into my normal design process, I will use it!”
- Architect, Denver CO

3D-CAD TO ENERGY SIMULATION – 4 EASY STEPS

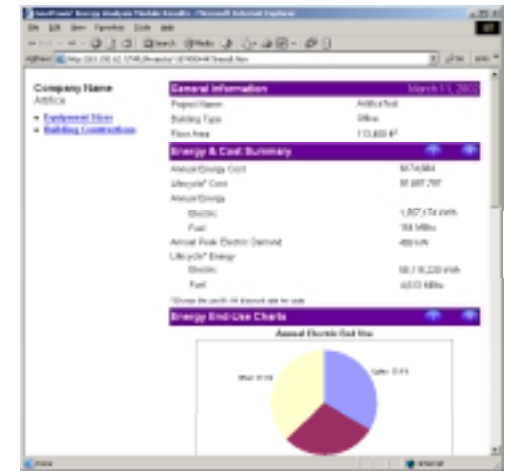
Step 1. Build a simple 3D model in a gbXML compliant CAD tool (e.g., DesignWorkshop).



Rendering in DesignWorkshop by Artifice Inc.

Step 2. Through the CAD tool's interface, specify the building's type and zip code, and auto-submit the file to GeoPraxis' EAM (www.GreenBuildingStudio.com).

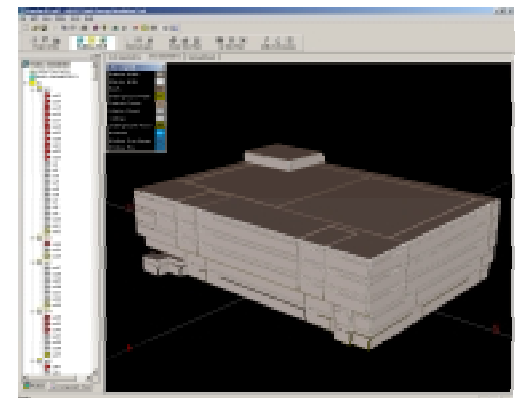
Step 3. View the energy analysis summary online or print to share with the client.



Step 4. Email the geometrically accurate energy simulation model to your HVAC engineer or energy code consultant.

STOP PAYING ENGINEERS TO RE-ENTER DATA

Give the mechanical engineering team models they can readily open in software they already use to save time, lower costs, and avoid errors. No take-offs are needed!

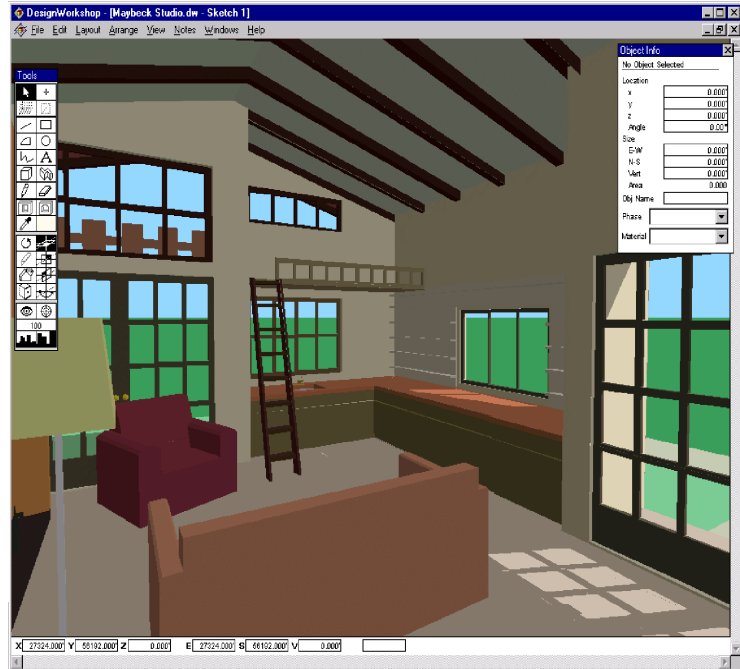


Open the same model in popular HVAC tools (e.g. eQuest/DOE-2 or TRANE Trace 700).



Focus Group Results and Analysis Report

Image: GreatBuildings.Com © Artifice, Inc.



September 1999

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In association with Artifice, Inc.



FOCUS GROUP RESULTS AND ANALYSIS REPORT ARCHITECTURAL DESIGN PROFESSIONALS

San Francisco, CA – August 10, 1999

Introduction

In the summer of 1999, GeoPraxis conducted a focus group of San Francisco Bay Area architects in support of the Conceptual Design Energy Analysis Tool Project (CDEAT). The CDEAT project¹ is a major multi-year effort to develop the Energy Analysis Module (EAM). The EAM will be an easy-to-use, energy analysis software module that will be integrated into existing 3-D CAD software tools. The best-known energy analysis program, DOE-2, (named for its major sponsor, the Department of Energy) will perform thousands of hourly simulation calculations for every building modeled. This powerful but traditionally hard-to-use program will be hidden within the kinds of 3D modeling and rendering tools that are currently on the market. The resulting tool is intended for energy non-experts, (primarily architects, lighting designers, design/build contractors, and developers) who will be able to generate reliable estimates of the energy performance of a building during in its earliest stages of design. The tool's what-if analysis capabilities will allow users to understand and test the energy-related impacts of their designs, including fuel and materials choices, system types, orientation, fenestration layout and other key decisions.

This focus group discussion concentrated on three major topic areas. These were:

- The use of CAD tools including 2D CAD drafting tools and 3D CAD rendering tools.
- “Green” building design practices and the consideration of energy and environmental factors during the design of buildings.
- Preferred formats for presenting green building and energy analysis results.

The ultimate purpose of the focus group was to elicit feedback from architects on the usefulness and preferred methods of integrating green building and energy analysis capabilities into 3D CAD design tools.

Attendees were recruited from the online database of architecture firms maintained by the Bluebook of Building and Construction (<http://www.thebluebook.com>). The recruiting plan was intentionally not designed to be representative of all architecture professionals. Instead we designed the recruiting script to attract the kinds of individual architects most likely to be among the early adopters of the EAM technology. Rather than attempting a random sample, we identified the purpose and sponsors of the project up front. As a result we were able to recruit participants who were experienced CAD users and already interested in green building design issues and energy efficiency. A short screening survey pre-qualified only those individuals that:

1. Worked as professional architects
2. Personally used CAD tools

¹ The CDEAT project is funded by the California Energy Commission's Public Interest Energy Research (PIER) program and Artifice, Inc.

3. Worked at firms active in non-residential construction

The nine attendees included individuals representing a reasonably wide range of architectural firm sizes. The majority was made up of small practices. There were two mid-size firms who appeared to specialize in commercial and governmental building types. Finally there was also one very large international firm. The person representing the largest firm was a senior level project manager whose work was predominantly in the commercial office building area.

Table 1. Characteristics of Attendees and Firms They Represented

Title	Residential	Non-Residential	Number of Employees	Primary CAD Tool	Secondary CAD Tool
Associate	10%	90%	40	AutoCAD 14	
Project Architect	10%	90%	35	AutoCAD 14	
Principal	15%	85%	8*	AutoCAD 14	
Project Manager	30%	70%	4	AutoCAD 14	
Principal Architect	40%	60%	5	MiniCAD (VectorWorks)	FormZ & AutoCAD
Senior Architect	60%	40%	7	AutoCAD 14	
Architect	60%	40%	4	MiniCAD (VectorWorks)	
Project Manager	70%	30%	4	AutoCAD 14 (2D only)	
Project Manager	0%	100%	200*	AutoCAD 14	DrawVision

* Significant international experience.

There was one small and very savvy firm present that used 3D CAD tools extensively in their practice. This firm consisted of fairly recent architectural graduates who had developed their CAD skills in architectural school. Their practice was primarily in the residential area. They did have an interest in energy but they didn't seem to fully understand the energy implications of their designs. This was characterized by their description of a predominantly glass house that they had designed.

One firm had a practice focused on space planning and tenant improvements. Their energy considerations typically did not go beyond lighting. Their projects were typically always work within a building shell where all of the HVAC, siting, orientation and construction type design decisions had already been made. In many cases, these were existing buildings where modular partitions were being rearranged. This firm did not use 3D CAD tools often and likely would not need or use energy analysis tools.

With the exception of one firm, the attendees were from San Francisco. The one exception was a small 'gentleman's practice' meaning that they appeared to operate at a slower pace and took on selective small projects. Their practice focused in on energy efficiency and 'green buildings' and they reported regularly using energy analysis simulation and 3D CAD tools.

CAD Tool Use

All present said they use 2D CAD tools everyday in their architectural practice. Three reported personally using a 3D CAD tool at least once a week. AutoCAD is the predominant CAD tool in use by this group, used by all but one of the group attendees. Only one firm

reported having used AutoCAD Release 2000. The rest used AutoCAD Release 14. There were also two MiniCAD users (including the one non-AutoCAD user). One firm had both Microstation and ArchiCAD in their office but the attendee wasn't actively using either.

The group's reasons for selecting AutoCAD as a 2D drafting tool were as follows:

- It is a stable CAD platform in wide use by their engineering consultants, which makes it easy to share files amongst many users.
- It is customizable to individual preferences with keystroke controls of functions, which makes it fast and easy to use for experienced users.
- Third party add-ins that extend usability are widely available. These include add-ins for 3D wire-frame modeling.

The biggest area of dissatisfaction with AutoCAD is that it is not easy to learn and that even after the learning curve has been endured it continues to be complex and difficult to use. In addition, multiple users can't work on the same drawing at the same time.

3D CAD Tool Use

The group had an active discussion of how and why they use 3D CAD tools. The larger firms and the small firm with recent graduates were the most active 3D CAD tool users. Out of the attendees, four said that they use 3D CAD on a regular basis. Out of these four, three said that they use 3D CAD at least once a week. Three attendees indicated experience with 3D Studio and two reported using FormZ. However, it wasn't necessarily the designers and decision-makers in these firms who were using the 3D CAD tools.

But the realities of the real world is that... you have some very senior designers out there who don't know how to use AutoCAD, who still draw by hand or if they do use AutoCAD, they don't know how to use a 3-D program.

Only one of the firms present had designers that used 3D CAD extensively as a design tool. Their comment indicates the breadth of their use of 3D CAD:

In schematic phase, we usually mass out our project in terms of sites. Then it's a big tool during schematic for all our clients to get a feel for where the project is going. Through DD [Design Development], it's used as a design tool pretty heavily to explore spaces and light and acoustics. And then in CDs [Construction Documents] we don't really use it that much except for final presentation.

Among the majority of other 3D CAD users, the predominant reason for using 3D is to give their clients a feel for what the building will actually look like. According to a representative of one medium size firm, "Using CAD and any kind of 3-D modeling tool is just really helpful in explaining our projects." Another added, "It's also probably to inspire the client in terms of what we're creating for them, salesmanship." The trend with this group was to present the client with fully rendered 3D drawings much like the traditional hand-drawn and rendered perspectives.

FormZ appeared to be the 3D CAD tool of choice for those who personally use 3D CAD frequently. Two firms use AutoCAD's 3D Studio MAX.² Because of the complexity of 3D

² Of those present, there was no mention of DesignWorkshop by Artifice.

Studio Max, those firms who use it rely upon expert users who are not the designers and decision-makers on projects. Another user mentioned using Lightscape in their lighting studies.

In the mid-size and larger firms, typically one or two people in the practice are proficient in the use of 3D CAD tools. These key 3D CAD users are able to quickly take 2D CAD drawings and design sketches and turn them into rendered 3D CAD drawings.

These findings indicate an important disconnect in the process of making decisions regarding energy and green building considerations. Basically, most designers and decision-makers continue to work on paper and therefore would not typically have direct access to the 3D CAD integrated Energy Analysis Module. This is not to say that they couldn't have their 3D CAD expert users provide them the results of the energy and green building feedback that the Energy Analysis Module is designed to provide.

3D CAD tool user comments generally concerned the difficulty in becoming proficient in their use. 3D Studio MAX was thought to be also particularly computer memory intensive and difficult to use. The 3D drawing file sizes were noted to be quite large. One key comment was that it was difficult to impossible to go from 3D CAD design drawings to 2D CAD construction documents.

This represents a significant disconnect that effects the interoperability of energy simulation tools. Somehow, there needs to be a means of handing off and refining the building energy simulation model as the project proceeds from design to construction documents and construction. The capability to maintain interoperability will need to be provided on the energy analysis tool side rather than the CAD tool side. In other words, the Energy Analysis Module will need to be able to pass off files to other building energy simulation tools in order to maintain interoperability and meet this important user requirement.

Green" Design Practices

The topics of "green design" and "sustainable architecture" engendered lively and significant discussions but yielded no clear direction that defines how these concepts fit into current architectural practice. The flavor of the discussion provided a strong indication that green design and energy conservation are not drivers in current day architectural practice. The real driver in this area was seen as satisfying Title 24 energy conservation requirements. This was generally thought to be fairly easy to do.

...if this program is related to Title 24 Energy Compliance, I would use it on every project, because that's the driving force – you run energy calcs on the building to make it comply. But if you have a program where you can try different strategies, then I would certainly be interested, because we always have someone else run the calculations and we just pray that it's going to comply.

The primary reason for not considering green design and sustainable architecture is that the client doesn't demand it and is not willing to pay for it. Only sophisticated clients or those who are legislatively mandated to do so are considering green design and sustainable architecture. Pending state legislation and federal government regulations were mentioned as important factors, suggesting that demand for these services was likely to increase.

The working definition that the group agreed upon for green design and sustainable architecture is “we build our buildings and conduct our lives in a way that doesn’t diminish the potential for future generations to have the same resources that we do”. Delving deeper into what specific practices signified “green” design, participants listed the following:

- Daylighting design or bringing daylight into architectural spaces.
- Building siting and orientation, presumably to minimize solar exposure.
- Energy conservation in general with no definition of exactly what this means in daily architectural practice.

The group generally understood the concepts of selection of green materials, embodied energy, green ratings and emissions. There was no clear indication that they gave regular consideration to these as factors in their architectural practice. There was generally though, a high level feeling that the time was coming when green design and sustainable architecture would be an essential part of practice. Everyone agreed that they were seeing more and more professional emphasis and press coverage in this area.

There was concern in the group about a certain level of superficiality in current efforts to develop green building qualifications. They described firms that were exerting minimal effort such as specifying recycled materials and calling themselves green architects. Everyone present felt that being a green architect required much more than just that.

It was evident that a tool such as the Energy Analysis Module would be a powerful adjunct to the architect exploring green alternatives. This would be especially true if the EAM provided pathways and connections out to green building information and specification material. For instance, it was noted that the American Institute of Architects and publications such as *Environmental Building* were beginning to provide green building resources. The following comment appeared typical, even for users that were only marginally committed to green alternatives:

If you are trying to do something new into the building design, then you have to do some research and study if time allows. It would be great if there were a tool that would help you analyze these things that you could simply plug in and do some numbers in a simple envelope. Just spit out at least some guidance that would help you go in that direction.

There was considerable discussion about barriers to integrating green considerations into design practice. The most significant barrier, as mentioned earlier, is getting the client to pay for the time spent investigating green building considerations. Other significant barriers revolve around this and include:

- Where to find reliable green building information.
- Getting the whole team on board up front and early in the project including the consulting engineers lighting designer and owner.
- Cooperation of the building contractor in fairly pricing and working with green materials.

Overall, the problem is finding the interest, time, money and information resources that allows green building considerations to be integrated into an already constrained practice. According to one attendee experienced in this area,

We've tried many projects where we've introduced green, so-called green objectives, sustainable objectives, only to not have enough time to really evaluate the first costs, life cycle costs, paybacks, [it's] schedules that are just so tight. Time is the constraint. It's the worst enemy.

There was discussion about the value of providing a software tool that integrates green building considerations into the design process. There was consensus that it would be very valuable. One participant ventured that they would be willing to spend as much as the cost of a CAD software package to get this level of functionality.

However there was also concern that if not priced properly, these capabilities could end up being too expensive and priced out of reach of many potential users.

...you guys are trying to come up with a little piece of software here that's supposedly going to be this little magic piece of software that everyone is going to want to use it, just because you can do energy calcs... Don't come up with some product that is going to be able to solve our problems sticking to the software programs, raise its price up a few thousand dollars. As it is, one is very reluctant to buy even add-ons. When AutoCAD was out by itself, you had a hard time just buying Soft Desk just to make it run the architectural product.

These findings suggest that different user group segments will likely have very significant differences in their perceptions of the price/value of the EAM.

Energy Analysis Practices

There was general consensus that complying with Title 24 was relatively easy. "Yeah, just meeting Title 24 isn't any big deal," said one, followed by another who added, "I've never yet just seen a building that would get knocked off the scale".

The techniques for complying are pretty much ingrained into the current state-of-the-art practice of architecture in California. Participants hardly ever had to go back and make significant changes to their designs in order to bring them into compliance.

There was comparison of green building considerations to Title 24 compliance. If it were a required part of getting a building permit then of course everyone would do it. This brought on a discussion about relegating Title 24 compliance documentation to specialized consultants at the end rather than the beginning of a project. The big disconnect here is that at this point, it is too late to make significant changes in the make-up of a project.

The participants felt that a tool such as the EAM, which provided relative indications of the degree of Title 24 compliance during the design process, would be useful. According to one:

So what would be helpful for me is a tool that would help do schematic design to give us ballpark figures, rather than like [at] 80% schematic to give it to the Title 24 guy to see that we're way off. I mean, for me it [would be] like something that could help me get ballpark figures through the very beginnings of the project. Especially for our residential projects, which is mostly what we do. That would be a lifesaver.

There was concern by one of the participants that the feedback needed to be general in nature and less specific to Title 24. A significant portion of this person's practice was conducted outside of California where Title 24 doesn't apply.

Look and Feel Issues – Data Inputs

There was considerable discussion about the likes and dislikes of tools that they currently use. This discussion in particular, centered on AutoCAD. The important conclusions from this discussion were:

- Everyone liked AutoCAD's flexibility in the sense that you can make the interface be whatever you want in terms of add-ins and functionality.
- It was generally felt that the interface to AutoCAD is choppy, not intuitive, and is difficult to learn.
- Keystroke access to controls is a very important feature of AutoCAD.
- The participants liked the fact that they can start out with their own customized project templates in AutoCAD.

Features from a number of other programs were also discussed. Major conclusions included:

- 3D CAD is difficult to learn and use once you get beyond the most basic of forms.
- With 3D CAD, it is difficult to render realistically without spending a great deal of time.
- To solve this problem, scanned photographs provide a good basis for rendering 3D CAD models
- Senior designers in large firms work on paper and are not proficient in 3D modeling. This is generally because they are primarily an older group that went to architectural school and started practice before computers were prevalent.

Finally, one attendee pointed out that 3D CAD model files are very large which makes it nearly impossible to integrate them into the 2D CAD construction document phase of a project.

First of all, not everyone does energy calcs all the time. First of all, most people don't model projects all the time. And even if they do model, the biggest pain in the butt is that the models are really large and you're not going to take this large model, turn it into construction documents, no matter what they say the software can do... I don't know about you guys but for most people, file size storage is a very big part of your budget in your server.

The key implication here for the EAM tool is that it needs to be easy to use. In technical terms, this means it likely should have significant high level defaults, user-customizable templates, and possibly even step-by-step wizards so that the user can begin to get results without expending a lot of time. The need for defaults and the level of detail that a user is willing to specify are further elaborated on as follows.

- Building level defaults are the fastest way to get the user started with the EAM process.
- Some users will be willing to go down to the space level in specifying defaults such as occupancy type but this will typically occur later in the design process.
- There is a fairly high level of reluctance to go into construction materials early in design process. Users want to default to construction type at a high level

- Architecture-oriented EAM users likely will not specify the mechanical system type early on in design. They typically depend on their engineering consultants for this type of information.
- Default information such as typical mechanical system type for the building and occupancy type would be useful.

In general, participants liked the idea of defaults at a high level with the ability to drill down into detail as the project progresses or as desired. According to one attendee:

I think part of it is that you have to ask a lot of those questions up front. And to leave it too wide open [initially], I don't think helps in the chore. The more attributes you can identify, the more stuff you can put in and define, the better off you are going to be in the long run. The better information that is going to get found.

One participant thought that the default specifications from the EAM would be very useful as a pre-design programming tool. In other words, they would like to have access to the EAM as a stand alone tool. They would enter occupancy type and building size and would be able to print out a list of defaults for construction type, mechanical system, etc.

There also appeared to be a strong preference for being able to initially specify the gross features of a building and then not be prompted for energy-related attributes as each new object is drawn.

I would like to be able to say, okay now I am going to work on an office building. Select that space type. Then not have to answer that everytime I draw a red triangle. But then go back if I want to and say, well, this is a conference room so that is really a different use. I am willing to go back to the menu and change that. But when I am laying out all these individual offices, I'd rather not have to keep going back.

Look and Feel Issues – Analysis Results

The final section of the focus group was a discussion of look and feel preferences regarding the results output. There was a general consensus amongst the participants that a graphic output was preferable to a numbers or text output. The participants liked the idea of comparative charts or graphs so that it is possible to see the progress as the design proceeds. This is similar to a “speedometer” concept, which gives a real graphic indication of whether the designer is doing better or worse, from an energy standpoint, as the design progresses.

There was considerable discussion on the format of the graphic output. This revolved around the relative benefits of tables, graphs, and comparative scales. While graphs seemed to be clearly preferred, there was no conclusive direction given here. This is a topic that will require further development and review of potential graphic formats before a final decision is made.

Participants liked the idea of isotherm or color-coding of problem areas in the 3D desktop. With this concept, the user would press a function key on the keyboard to turn on the isotherm view. Problem areas such as windows with excessive solar gain would be shaded with a color code indicating the order of magnitude of the problem. For instance, red would indicate a significant problem. Yellow would advise the designer to proceed with caution with

a particular design element. Placing the mouse pointer over the color-coded element could present a dialogue box with information about the problem or strategies for solving the problem.

It was generally felt that a comparative baseline was important, but there was a bit of debate about what such a baseline should include. A fundamental requirement agreed to by all is the need for a comparison to a Title 24 compliant baseline building giving a relative indication of how their design compares to the mandatory energy code. But opinions diverged when it came to the usefulness of benchmarking higher performance buildings. One designer of primarily smaller commercial and residential spaces was clear that he did not want to see his building compared to “A [case] study project that was some pretty fancy building that we don’t have the budget to build”.

On the other hand, the more green-oriented designers were equally adamant that it was important to be able to compare to a showcase high performance or best-practice building. When asked if some intermediate baseline might be appropriate, one architect said, “Energy Star at least for crying out loud. That is easy... You know when you buy a refrigerator and you see it has Energy Star, you know it is decent at least.”

The participants were asked to rate on a scale (1-7) the usefulness of the types of results that a tool like the EAM might be able to produce. Energy use, energy cost, and energy loads, and energy end use breakdowns were all rated as highly useful. Green building scores, pollution produced estimates, and embodied energy estimates also received high ratings. Monthly estimates consistently received lower ratings than annual estimates.

While these results appear to make sense, the fact that they were derived from such a small sample will require further investigation before a final decision is made on how to proceed with the EAM development. One concept suggested by these data might be to allow the user to customize which results they receive and the order in which they are presented.